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AND

FOUNDATION WALLS,

FOR ALL CLASSES OF BUILDINGS,

PILE DRIVING, BUILDING STONES & BRICKS,

PIER AND WALL CONSTRUCTION, MORTARS, LIMES, CEMENTS, CONCRETES, STUCCOS, ETC.

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60 ILLUSTRATIONS.

PRACTICAL EXPLANATIONS OF THE VARIOUS METHODS OF BUILDING FOUNDATION WALLS FOR ALL KINDS OF BUILDINGS. TABLES OF THE WEIGHT OF MATERIALS, ETC. THE KIND OF MATERIALS USED, THE LOADS SUSTAINED, AND THE SIZES OF WALL PIERS, ETC. USE OF PILES IN FOUNDATIONS, WITH TERMS, ETC. PLASTERING, MORTARS, LIMES & CEMENTS. EXTRACTS FROM NEW YORK BUILDING LAWS, WITH NOTES.

BY GEORGE T. POWELL,
Architect and Civil Engineer, New York.

TO WHICH IS ADDED A TREATISE ON FOUNDATIONS, WITH PRACTICAL ILLUSTRATIONS OF THE METHOD OF ISOLATED PIERS, AS FOLLOWED IN CHICAGO,

BY FREDERICK BAUMANN, ARCHITECT.

REVISED BY G. T. POWELL.

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FOUNDATIONS.

By the term Foundation, we mean all that portion of any structure which serves as a basis on which to erect the superstructure. The object to be attained in the construction of all foundations is to form a solid base for the superstructure.

Foundations may be divided into two great classes.

First—Foundations constructed in situations where the natural soil is sufficiently firm to bear the weight of the intended structure.

Second—Foundations in situations where an artificial bearing must be made, in consequence of the softness or looseness of the soil.

Each of these classes may be subdivided into many kinds, under the heading of engineering works; but it is the intention to confine this book to Buildings more particularly.

FOUNDATIONS AND FOUNDATION WALLS.

CHAPTER I.

Foundations on Soil or Stratum not liable to be affected by Weather, Air or Water.—In building on a natural bottom of this kind, it is necessary to level the surface or footing space, so that the walls or piers may start from a horizontal bed. If irregularities occur in the firm ground, it will be best to fill them up with concrete, rather than to fill up with stone or brickwork. Where some portions of the foundations start below the level of the other, care must be taken to keep the mortar or cement joints as close as possible, or to execute the lower portion of the work in cement or hard-setting lime mortar.

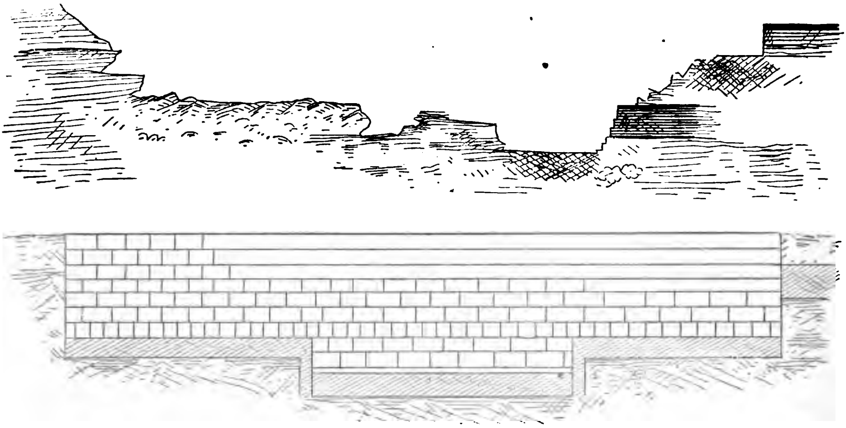
Strong gravel may be considered as one of the best soils to build upon, as it is almost incompressible, and is not affected by exposure to the atmosphere, and is easily leveled.

While sand is almost incompressible, and makes a firm foundation, it must be kept from shifting, or being acted upon by water.

In many cases sheath or board piles have to be driven and cement used.

Rock or partly solid rock bottom requires the judgment of an experienced architect or engineer; for it commonly happens, in the area of a large building, that some portions will rest on rock and others upon clay or loose gravel, and these irregularities, which are liable to produce settlement, are often difficult to make firm and carry the load of masonry without change. A common rule, when possible, is to reduce the rock to a certain level, sufficiently deep for the footings, and then remove the soft soil, and make a bed of say three feet of concrete for stores, and bring the concrete to the level of the stone; all of which is explained by the many practical illustrations in this book.

To prepare the surface of stone bottoms found natural, with irregularities or inclined strata, it is necessary to reduce the stone or brick to level surfaces, thus—



Illustrations 1 and 2.

or quarry, excavate, and carry the whole to a common level.

Beds of Rock with clay are not very safe without artificial treatment, especially if there are partings or strata of clay, and they lay in inclined positions. Thus, for instance,

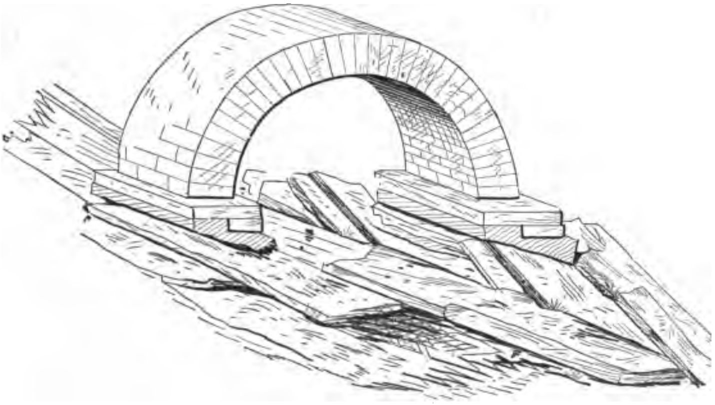


Illustration 3.

when turning arches, the springing line or base of arch on one side might be said to be secure, while the opposite side would be liable to move from the pressure of the load on the arch; this strata may be made secure by drilling, and driving iron bars into holes passing through the stratum.

When dry clay becomes wet or rammed around foundation walls it has a tendency to bulge them.

Clay.—The most deceptive kind of ground to build upon is clay. Its *insecurity* results from the position of its stratum, as well as its elasticity, from being mixed with marl, etc., and tendency to absorb moisture. In the dry seasons it is very firm, while in the wet seasons it is elastic and unreliable. It is known that whole buildings have been injured by the moving of clay strata. Of course this insecurity is not likely to occur on level stratum or firm clay.

But when the layers of clay are inclined, one cannot be too careful, especially when a structure is to be erected that shows great difference in the distribution of the load; for instance, in the use of piers along with solid walls, chimneys and towers. It is always well to disconnect towers.

All buildings settle a little, if from no other cause than the weight of the walls and floors.

Very bad shifting clay bottoms have been built upon by laying round timbers, one foot apart, on concrete; the space between the timbers being laid with concrete, and filled to the top of the logs, to receive stone-slab footings. This method is used on structures of about thirty feet in height, and not expensive buildings.

CHAPTER II.

Foundations on Soil Affected by Exposure and Water.—This class of foundations will be referred to with illustrations of factory foundation walls on Long Island and on the marshy ground back of Hoboken, where the weight of the structure is distributed over a large area of bearing surface. See illustrations 40 and 41.

To Secure Solid Foundations Underlying Soft Ground of Considerable Depth.—In cases of this kind, where the expense of bringing up a solid foundation from the hard ground is too great to allow this to be done, a number of supports must be brought up through the soft ground, on which to form a platform to carry the superstructure.

There is a variety of ways in which this may be done.

First. By excavating holes through the depth of the soft ground, and filling with sand. This is done by boring, or driving down a wooden pile; then withdraw it, and fill with sand. This method is not much in practice here, although a secure base may be made in this manner.

Second. Is by driving piles of wood or iron through the soft ground until they are firm and secure in the solid earth.

Third. By screwing piles into the soft ground until they reach the firm ground, and into the firm ground for a bearing. This method is used more particularly in Docks and Railroad works. These piles are usually cast or wrought iron cylinders, from three inches to eight inches in diameter, and have at the foot a cast-iron screw, with a blade from eighteen inches to five feet diameter. They are screwed down into clay, sand or coral, from ten to twenty feet in depth, by men using capstan bars; but on engineering works, where many of these have to be sunk, there is a machine, made for the purpose, that has four cranks; thirty-three revolutions of the crank makes the pile revolve once; they may be acted by steam. I have never known of any of these to be used for foundations in New York, except on the river edges. They are very expensive for buildings.

There is a soft kind of soil that piles driven into would only have a tendency to stir into a mud-batter. Instead of driving piles, it is much better to bore holes with a large auger to a considerable depth, and to fill with sand, which, from its property of acting as a fluid, is a most valuable material for distributing pressure over a large area of surface. A sand-pile transmits the pressure laid on it, not only to the bottom, but to the sides, and does not injure the ground by vibration.

Fourth. By hollow cylinders of cast-iron, or cast-iron pipe, lowered until they rest upon the bearing stratum; the soft material being removed from the interior of the cylinder to enable it to descend. If used to resist sea-water, the iron should be close-grained, hard white metal. This quality of iron is known to resist the action of saline salts or chlorides of sodium for at least forty years. But poor quality of iron is eaten by the salt, and becomes soft.

Large cast-iron cylinders, from two to five feet in diameter, are used for piles. They are usually cast in lengths, say from eight feet to sixteen feet in length. Short lengths are sometimes connected by internal flanges or lap-joints—the first pile sometimes is provided with a seat, having cutters or a screw fixed with a compression ring after the pile is set.

On buildings this system of piles may be used with advantage for towers, chimneys and heavy structures.

Boring to Test the Bottom.—Boring in common soils or clay to test the bottom, may be made fifty or sixty feet in a day or two, by a common wood auger, two inches in diameter, turned by two or four men with three feet levers. This will bring up samples of the soil. The iron of the jointed rod should be of the best quality. When the testing has to be made to a considerable depth, it may be necessary to drive down a tube of wrought or cast iron, to prevent the soil from falling into the open hole. These tubes may be in short lengths, for convenience of driving, connected with screw-joints, and the earth may be removed within by a scoop with a long handle.

Timber-Pile Foundation.—Timber piles are objectionable when partly out of water for permanent structures, where they *cannot be renewed.* For that reason, when they are used for foundations, they are cut below the water line or line exposed to air. The oil of tar put on piles has prevented the boring of worms. The use of timber piles is very general on Manhattan Island, the site of New York City, and numerous examples may occur to the mind of the reader. We believe this to be important, and will proceed to explain the use and manner of driving piles.

First. We may consolidate the soft or yielding ground by driving piles into it, until it becomes so compressed that the piles are prevented from sinking by lateral friction.

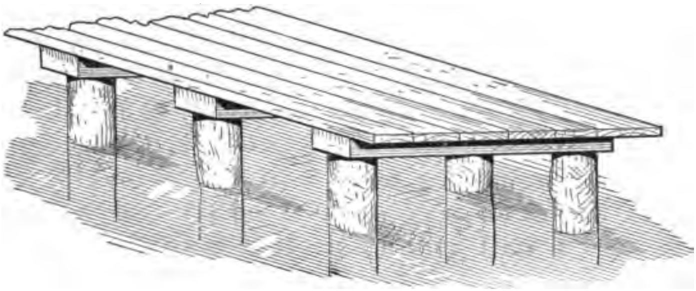


ILLUSTRATION 4.—Piles, &c., showing Water Line.

The usual method in New York and other cities, when the contractors have removed earth of say ten feet or less in depth, is to drive sheet or sheath piles to sustain the earth of the streets, and continue to carry the sheet piling down as the excavation proceeds. After this preparation they then proceed to drive piles, from sixteen inches to two and three feet apart, after which the earth is removed, and the piles are cut down to a level below (air) or water line; a depth of say two feet of concrete is filled in up to level of the top of the piles; the whole is then planked over to receive the masonry of the superstructure. Sometimes the planking is laid, not on the piles, but on a net-work of horizontal timber. In timber piling the load is transmitted only in the direction of its length.

Pile Driving.—The usual method of driving piles is by a succession of blows given by a heavy block of wood or iron, called a ram, monkey or hammer, which is raised by a rope or chain, passed over a pulley fixed at the top of an upright frame, and allowed to fall freely on the head of the pile to be driven. The construction of a pile-driving machine is very simple. The guide frame is about the same in all of them; the important parts are the two upright timbers, which guide the ram in its descent. The base of the framing is generally planked over and loaded with stone, iron, or ballast of some kind, to balance the weight of the ram. The ram is usually of cast-iron, with projecting tongue to fit in the grooves of frame. Contractors have all size frames, and of different construction, to use hand or steam power, from ten feet to sixty feet in height. The average height most in use is one of twenty feet, with about twelve hundred pound ram. In some places the old hand-power method has to be used to avoid the danger of producing settling of adjoining buildings from jarring.

Piles should be driven to sink not more than one inch to the last blow from the hammer. The hammer used should be equal in weight to the pile. The common size of piles is ten to fourteen inches in diameter, and are driven with hammers or rams weighing twelve hundred to two thousand pounds each. The diameter of the pile should be about one-twentieth of the length.

Terms used in Pile Driving.—A *Pneumatic Pile* is one driven by atmospheric pressure, when the air is exhausted from within; of course these must be cylinder or hollow metal piles.

A *Hollow Pile* is a cylinder, which is sunk by excavation proceeding inside.

A *Screw Pile* has an auger at the lower end, and is sunk by rotation, aided by pressure.

A *Close Pile* is one of whole timber, set close to the others.

A *False Pile* is an additional length added to a pile after driving.

A *Filling Pile* is to fill the space between gauge piles.

A *Foundation Pile* is one for supporting a structure.

A *Gauge Pile* is a preliminary pile to mark the desired course.

A *Guide Pile* limits the field of operation.

A *Sheet Pile* is of half timbers in contact, filling the gaps between gauge piles.

A *Wale* is a horizontal string-piece to bind the piles.

Pile Hoop, a band around the top to prevent splitting.

Pile Shoe, the metallic point.

Test Pile, the first pile driven to test the bottom; should be not less than six inches in diameter.

Size and Kind of Wood for Piles.—Piles are generally round, and from nine to eighteen inches at top, and should be straight and clear of bark and projecting limbs, etc. But where piles are exposed to the rising and falling of tides, for wharves, trestle-work, etc., they are considered to be the best if driven with the bark on. Trees are sometimes selected for this purpose; and when the foliage is full, just on the change, the tree is girdled—that is, the bark near the bottom is separated by cutting it off sufficient to kill the tree, and two or three months later the trees are felled. This method shrinks the bark close to the wood.

White pine, spruce, or even hemlock answer very well in soft soils. Florida yellow pine make the best, and oak, elm and beech for more compact soils. They are spaced from two feet to four feet to centres. Squared piles and tapering ones will not bear equal loads. Have all as near uniform in size as possible.

All timber, driven into the earth, having the common name of piles, may be divided by calling all those that stand on solid foundations Posts, and those that depend on the friction of the earth and its constituents are Piles, and require to be considered very carefully for their sustaining ability. Although these piles may resist the hammer of the machine, yet sometimes it is impossible to tell how much is a firm stratum, or how much is friction. In such cases always allow a large proportion for safety, and bind the piles together, or brace them. In nearly all calculations that are made for pile driving, the calculations are based on the soil being *homogeneous* (that is, *assume* it to be)—that is, that the soil is the same kind all the way down. Now this seldom occurs, as there may be alluvium, clay, gravel, marl, shale or pebples, and some variety occurs in nearly all localities. As it is difficult to find a locality to suit the formula, it is best to accept the judgment of experienced builders, who are experts in this specialty, guided by the information here contained.

The force in pounds with which a pile hammer makes its blows upon the head of a pile is very indefinite, as all the rules differ very much. Correct data may be gathered from actual tests, as follows: In the fine stone London Bridge crossing the Thames, each pile sustains eighty tons. They are driven only twenty feet in the stiff blue London clay, and are four feet to centres, and were twelve inches diameter in middle. This proved too much of a load. At about three feet, they would have had only forty-five tons to sustain. Trautwine states that at the Chestnut Street bridge, Philadelphia, the greatest weight on any pile is eighteen tons. Mr. Kneas had the piles driven until they sank three-quarters or .75 of an inch, under each blow, from a 1200-pound hammer, falling twenty feet. Here we have the fall in inches: 20 x 12 = 240 inches, divided by .75 = 320 x 1200 lbs. = 384,000 lbs., divided by 8. = 48,000 lbs, or 21¼ tons safe load; but it is best in practice to use only one-half of the load as safe.

Here is another: The refusal of a pile intended to support a weight of thirteen and a half tons, can be safely taken at ten blows of a ram of 1350 pounds, falling twelve feet, and depressing the pile eight-tenths of an inch at each stroke.

Another: Some engineers consider a pile safe for a load of twenty-five tons when it is driven to the refusal of 1350 pounds, falling four feet, not to sink more than four-tenths of one foot under thirty blows. On mud and marsh bottoms it is best not to load the piles more than one-quarter of the above table.

Here are a number of rules for calculations in reference to the strength and bearing capacity of piles.

To find the Safe Load which the Pile is to Carry.—Given: The weight of ram, the height the ram falls in inches, and the set of pile at last blow, in inches.

Rule—Multiply the weight of ram by the height it falls, and divide the product by eight times the set of pile at last blow.

To find the Height for the Ram to Fall in Inches.—Given: The set of pile at last blow in inches, the safe load which the pile is to carry in cwts. (of 112 pounds), and the weight of ram.

Rule—Multiply the safe load which the pile is to carry by eight times the set of pile at last blow, and divide the result by the weight of ram.

To find the Set of Pile at last Blow.—Given: Weight of ram, height the ram has to fall in feet, and the safe load the pile is required to hold in cwts. (of 112 pounds.)

Rule—Multiply the weight of the ram by the height it falls, and divide the product by eight times the safe load which the pile is to carry.

To find the Weight of Ram in cwts. (of 112 pounds.)—Given: The set of pile at last blow in inches, the height the ram is to fall *in inches*, and the safe load the pile is to carry in cwts. (of 112 pounds.)

Rule—Multiply the safe load the pile is to carry by eight times the set at last blow, and divide the product by the height the ram falls.

Pile drivers who are experts know when their piles strike rocks, and sometimes band the tops to prevent them from swaying.

Here are the results of experiments on piles at Fort Montgomery: The piles were twelve to sixteen inches in diameter, and nine to fourteen inches at the smallest end, and were from twenty-nine to thirty-three feet after cutting;

were of spruce, and weighed about forty pounds per cubic foot. They were driven with a ram or hammer of 1630 pounds, at a height of thirty-five feet. The last blows made them sink from two and a half to six inches. Compressibility of soil about one-eighth of its entire bulk.

Experiments at the Brooklyn Navy Yard.—The piles were twelve to eighteen inches at top, and seven inches at foot; length of piles after cutting averaged thirty-two feet; weight of ram, 2240 pounds, and height of fall at twenty-five feet. Average number of blows, seventy-three. They were driven into fine sand, uniform in quality.

In starting all work of pile driving, a test pile, of six or eight inches diameter, should be driven to test the bottom, and of about the same length that it is the intention to drive the Foundation Pile.

The captain of a pile driver is supposed to know the best about soils in his locality—that is, down for a bottom underneath the ground.

A number of piles driven for piers, and a cast-iron cylinder sunk around them, and secured at the top, the earth removed inside, and filled with concrete, makes an excellent foundation.

Where timber foundations have to be constructed, and the posts or piles of wood are exposed to the rising and falling of tides and sea-water. The water and the shores in this country and others are infested with wood-boring worms and marine creatures, which in three to five years destroy ordinary timber. One of these is the *Limnoria Terebrans*, and are about three-sixteenths of an inch long. Thousands of these in some localities, assisted by the action of the sea, will soon cut a pile through, as the surface rots rapidly after being perforated by them. The other is the *Teredo Navalis*, and is also known as the ship-worm. It will penetrate the wood from fifteen to twenty-five feet below mean low tide. It is found in most countries. They grow to about three inches long, and one-quarter inch diameter, with a head like an auger, with the point gone. It is evident that the head revolves. They leave very small holes where they have entered, so that the outside would not attract attention, when the inside is completely honey-combed. Their attacks are generally confined to timber above the bed of the sea. Mr. C. G. Smith, C. E., mentions the ship-worm, and gives some particulars about the kind of wood that will remain sound longest in sea-water.

TABLE.

Beach (with Payne's patent process)		10 years, 7 months, first decay.
Teak Wood (East India)		5 years, 6 months, first decay.
English Oak (Kyanized)	5 years, good;	10 years, 0 months, unsound.
British Ash	3 years, good;	5 years, 0 months, unsound.
American Oak	3 years, good;	5 years, 0 months, unsound.
Pitch Pine	3 years, good;	5 years, 0 months, unsound.
Yellow Pine	3 years, good;	4 years, slightly unsound.

It appears that they do not so frequently attack bark, as it kills them before they penetrate. If the outside could be shrunk with heat, slightly charred, and coated with carbolic paint, mixed with Trinidad asphalt, it is thought this will give great protection. Copper lining has sometimes been resorted to, but this is too expensive for such structures generally. There is an English Silicate Paint used: not readily affected by water; and when there is a covering on the silicate with asphalt or tar and oil, it is believed to act with success.

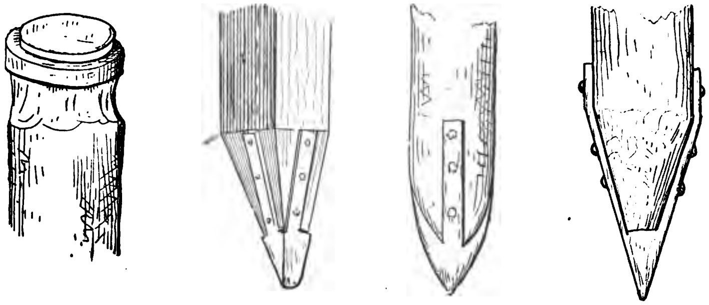


ILLUSTRATION 5.—Wrought or Cast-iron Shoes to Piles.

Another method: All that portion of the pile exposed to the action of sea or fresh water, should have a coat of crude carbolic paint. When this has dried, put on a coat of asphalt hot, and wrap coarse canvas or bagging fabrics spirally around the pile, saturated with hot asphalt; and when this has set, finish with another coat of asphalt hot. After this it is ready to drive. Piles treated this way are not attacked.

Before closing this chapter, I will state that "it is important that every foundation, for either small or large structures, should be prepared to sustain the load of the walls, the materials of the building, and the load to be sustained on each floor." The result of these, added together, gives the load to be sustained (with an average of thirty pounds per square foot on roof for snow). *And the foundations should be made so firm that no doubt will arise about their being insecure.* It often occurs that excavations are made, and structures are started, so that when complete questions arise about their *being secure*; and then perhaps there is no remedy; and if one, that very expensive.

CHAPTER III.

Excavations.—Under this heading it is thought best to give abstracts of a revised ordinance of New York City, relative to the Construction of Vaults (similar laws in reference to vaults and areas should exist in other cities) with the rates to be paid on permits, *i. e.:*

"A permit must be taken out before excavation, or legal proceedings will be instituted against the owner or builder."

"SEC. 1. Empowers the Department of Public Works to grant permits for the construction of vaults in the streets, provided, in their opinion, no injury will come to the public thereby.

"SEC. 2. Forbids the construction of vaults in any street in the City of New York without permission in writing from said board, under the penalty of one hundred dollars.

"SEC. 3. Applicants for permits must state the name of the owner of the premises in front of which the vault; the purposes for which the building is or is intended to be used; the number of square feet to be occupied by the vault, including its walls; and the proposed length and width of the same.

"**Rule required to be complied with**:—When applications for vaults are made, such applications shall in all cases be accompanied by a plan drawn upon a scale of one-fourth of one inch to one foot, showing the whole area to be built, including walls, and designating the open area, if any, and also the space to be exclusively used for stairways (see Sec. 15); and in case there shall be any fire hydrant in front of premises where the vault is to be excavated, the position of such hydrant shall be shown on such plan, and there shall be a space of two feet left around the hydrant.

"SEC. 4. Requires that payment for each square foot of ground to be occupied by the vault shall be made on obtaining the permit, under the penalty of one hundred dollars.

"SEC. 5. Prohibits the construction of vaults beyond the line of sidewalks or curbstone, under the penalty of two hundred and fifty dollars. *It is to be distinctly understood* that the permit gives no authority, and it is strictly forbidden, to disturb, by excavation or otherwise, any water hydrant, or stop-cock, or stop-cock chamber, or water pipe; or do anything to prevent the proper use of any hydrant or stop-cock, or expose them to freezing.

"SEC. 6. Makes it the duty of the person obtaining a permit to deliver to this board a certified measurement by one of the city surveyors of the ground occupied by the vault before the same is covered, under the penalty of one hundred dollars.

"SEC. 7. If it appears by such certificate that the vault occupies a greater number of square feet than shall have been paid for, the owner of such vault, and the master builder under whose direction the same shall be constructed, shall, in addition to the penalty imposed in and by section 4, severally and respectively forfeit and pay twice the sum previously paid, for each square foot of ground in excess of the number of square feet previously paid for.

"SEC. 10. During the time of constructing vaults a lamp or lantern shall be kept burning the whole of every night, which shall be placed so as to cast its light upon the opening, under the penalty of ten dollars.

"SEC. 11. All vaults must be completed and the ground closed over them within three weeks after they are commenced, under the penalty of five dollars for each day they may remain uninclosed after that period.

"SEC. 12. No area in the front of any building in the City of New York shall extend more than one-fifteenth part of the width of any street, nor in any case more than five feet, measuring from the inner wall of such area to the building; nor shall the railing of such area be placed more than six inches from the inside of the coping on the wall of such area, under the penalty of two hundred and fifty dollars, to be recovered from the owner and builder thereof severally and respectively.

"SEC. 14. Every description of opening below the surface of the street in front of any shop, store, house or other building, if covered, shall be considered and held to be a vault within the meaning of this chapter, and the master builder, or owner, or person for whom the same shall be made or built, shall be liable to the provisions, payments and penalties of this chapter severally and respectively.

"SEC. 15. The last preceding section of this chapter shall not be constructed to refer to those openings which are used *exclusively* as places for descending to the cellar floor or any building or buildings by means of steps.

"Payments for vault permits must be made on taking out the permit, as follows, viz.:

"For permission to construct a vault in front of any building, seventy-five cents per square foot.

"Where it is proposed to increase the superficial area of any vault, the increased area is only to be paid for at the above rates. In such case the surveyor certifying to the dimensions of the new vault must also certify to the dimensions of the old vault.

"It will be seen by section 14 that excavations commonly known as areas or parts of areas, if covered, are to be paid for as vaults, excepting such space only as may be occupied by steps for descending to the basement or cellar floor."

The preceding laws in reference to vaults and areas are very effective in New York, and similar laws should exist in all cities to protect the owners of property, pedestrians, vehicles, and business generally during the construction of buildings.

A further permit is required before excavation and the commencement of work in the foundations. This permit has to be obtained from a Board known as the Department of Buildings in the City of New York. Some other large cities in the United States have Department of Buildings or some laws that strictly pertain to buildings. The requisite information in regard to the New York laws on this subject will be given under the heading of Walls, etc.

Excavations.—Twenty-four cubic feet of sand; or, seventeen cubic feet of clay; or, eighteen cubic feet of earth; or, thirteen cubic feet of chalk, equal one ton. One cubic yard of earth before digging, will occupy about one and one-half cubic yards when dug, and contains twenty-one striked bushels, and is considered a single load; or, double this a double load.

Footings and Footing Courses.—In commencing the erection of any building it is usual to spread the bottom courses of the masonry beyond the inner and outer face of the walls; the spread courses are termed footings, and distribute the weight of the structure over a larger area of bearing surface; the liability to vertical settlement from the compression of the ground is greatly diminished.

In the case of isolated buildings standing on a small base, they give a great protection and resist the force of high winds, storms, etc.

For instance, take the case of a chimney shaft one hundred feet high, standing on a base ten feet square, and exposed to heavy gales. The compression of the ground from the force of the wind that would cause a depression of one-quarter of one inch, would cause the chimney to be out of centre five inches. If the base is increased to twenty feet square, we not only increase the leverage to resist the force of the wind, but the sustaining surface is quadrupled; so that the resistance is eight times greater than in the first instance. Footings, to be effective, must be bonded into the body of the work, and of sufficient strength to resist the cross-strains to which they are exposed. It is a common practice among mason builders, whether the materials be of brick or stone, to simply comply with the requirements of the plans, lay the footings down, pay no regard to bonding, and leave the unequal settlement of the walls to chance. This, of course, does not occur with men skilled in their trades.

In Building large Chimneys for Manufactories, the size of the chimneys and the height should be determined by proper experts, and with the opinion of the Engineers.

Rules for Chimneys:—The area of the chimney should be three-quarters that of the opening over the bridge; viz: one and one-half inch per pound of coal consumed; or, nineteen and one-half inches for each foot of fire surface burning thirteen pounds per hour. The whole diminution of flue should be gradual, and not by any offsets. A common rule for size of chimneys is, that the minimum area of chimneys twenty-four to thirty yards high is four hundred square inches for each twenty horse power.

Chimneys of any considerable height should be tied, clamped, or anchored with wrought iron straps, etc., at not less than every twenty-five feet in height.

The highest chimney stack in England is at Bolton; it is 367 feet from the surface of the earth, octagonal in plan, 14 feet 0 inches for each side, and 112 feet girth at bottom. Thickness of brickwork at bottom, 8 feet; thickness of brickwork at top, 1 foot 6 inches; 5 feet 6 inches on each side at top, or 44 feet girth. The top is finished with stone.

The chimney of the Edinburgh Gas Works is 341 feet 6 inches high. It is 329 feet from the surface of the earth. Stone foundation 40 feet 6 inches, by 6 feet 6 inches deep; 30 feet square at ground line, 27 feet 9 inches square at top of stone pedestal; on top of this the brick shaft is 264 feet high; 26 feet at the bottom diameter, and 15 at the top.

In the construction of large chimneys, and particularly isolated ones, they should be built with great care, the mortar being prepared every day, of one of lime to two parts of sharp sand; or, of cement and sand. The masons should change positions and level and true the work often, to equalize the difference in the work done by different men; select competent men for the work.

The Foundations and Trenches for Footings should be cleared of all rock, rubbish or soil, and leave the site of the intended building clear and unincumbered; and make perfectly level and hard the bed of all trenches, and consolidate the earth about the same.

Foundations in cities are usually excavated according to the survey furnished by one of the City Surveyors. Out side of the city, for suburban or country buildings, the excavations are generally made direct from the plans. After the earth is removed, either in city or country, it is necessary to lay out the base-walls of the structure with lines, secured to stakes driven in the ground. The common method is to establish one line, call it a *base* line, running parallel with the street line curb or fence line, as the case may be. From this, where no side-walls control the lines of the building, it may be necessary to produce a line square, and at right-angles to the *base* line, which is usually done thus: Draw the line tight, and as near a right angle to the base line as possible; then true it by using a rod laid off in feet. After you have commenced, and have a long line to square, it may be necessary to increase the angle in laying out to twelve feet, sixteen feet and twenty feet. After this the square may be tested on the lines by using a rod thus:

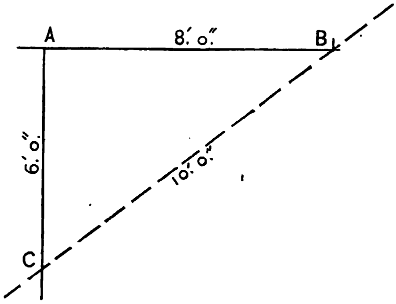


ILLUSTRATION 6.

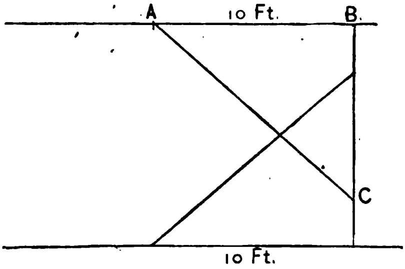


ILLUSTRATION 7.

Take any angle, *A*, *B* and *C*, on one side with three measurements, and try the same on the other side. This has to be tested very carefully. Some masons have very large wooden squares for the purpose, which are far more preferable than deciding by sight, or even measuring on the line.

Another method of getting a right-angle: To erect a perpendicular line at any point on the base line *A B*, set one point of compass or rod to sweep a radius at *B*, and describe the arc of a circle; use the same radius, and put one point at 1, and intersect the line at 2, then produce a line from 1 to 2. Use 2 as a centre of same radius, and draw a curve, then produce and continue the line 1 to 2 to 3. Then draw the line from *B* to 3, and this gives the desired angle. After this is done once or twice, it is very simple. Circles, polygons or ellipses are best when laid out on a wooden template.

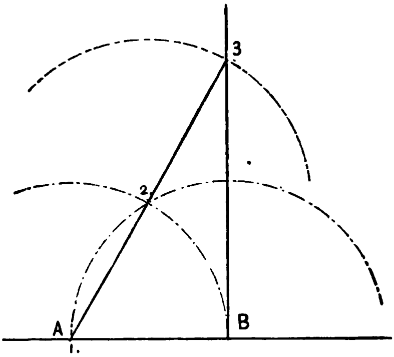


ILLUSTRATION 8.

CHAPTER IV.

Stone Foundations, Walls.—The bottom stones of course sustain the load or weight of the building, and hence the greater the risk arising from any irregularities in the bedding of the stone. To avoid this, the stone should be dressed true, no spalls used, and properly bedded. In New York City the foundation or base-stones—nearly all of which come from quarries on the island—are of Gneiss, a kind of granite, which crops out above the surface in irregular strata. It is a metamorphic rock, and lays northwest; it is only useful for foundations. The others are common building stone, and a blue kind of limestone.

No back joints should be allowed beyond the face of the upper work, except where the footings are in double courses, and every stone should bond into the body of the work several inches at least. Unless this is attended to, the footings will not receive the weight of the superstructure and will be useless. See figure.

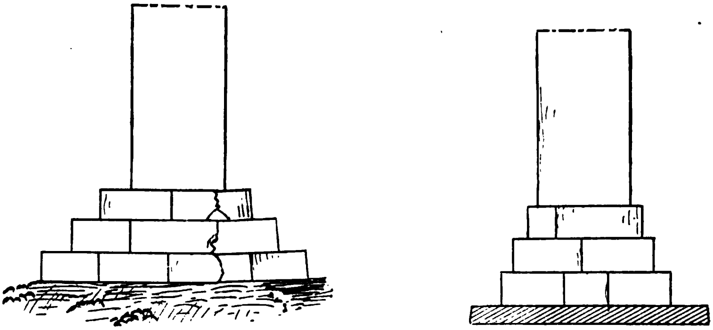


ILLUSTRATION 9.

In fixing the spread of the footings or foundation courses of the masonry or brick-work of ordinary walls, the usual rule is to make the breadth of the base one and one-half the thickness of the body of the wall for and on compact gravel, and twice that thickness for sand or stiff clay.

The following principles should in all cases be observed in the building of all kind of stone masonry: To build the masonry as far as possible in a series of courses perpendicular to the direction of the pressure they have to sustain; avoid all continuous joints and break-joints; use the largest stones for the foundation courses; lay all stones with layers or beds so that the pressure will act directly perpendicular to the direction of the layers; *i. e.*, by laying the stone on its *natural bed.* This is of primary importance to strength and durability.

Moisten the surface of dry and porous stone before bedding them, which prevents the mortar from drying too fast, and being reduced to powder by the stone absorbing its moisture. Fill all the joints and all spaces between the stones with mortar; have such spaces as small as possible.

Stone-work is estimated by the perch of twenty-five cubic feet, or by the cubic foot.

Brick for Foundation Footings, etc.—The following are the principles to be observed in building with brick:

First. Reject all bad shaped and unsound bricks. Good bricks are regular in shape, with plane surfaces and sharp, true angles. They give a clear ringing sound when struck. When broken, they show a compact, uniform structure. Should not absorb more than one-fifteenth their weight in water.

Second. Place the beds of the courses perpendicular to the pressure which they sustain. Make the bricks in each course break joint with those of the courses above and below, by overlapping from one-quarter to one-half of the brick. Cleanse the bricks, wet them thoroughly before laying to avoid aborbing the moisture in the mortar too rapidly. Fill all the joints with mortar, taking care that the mortar shall not exceed one-quarter of one inch; lay four courses to ten inches, or four courses to twelve inches, accordingly as you use different thicknesses of brick, and then only allow one-quarter inch for each joint. Use no bats or pieces of bricks.

The volume of mortar required for good brick-work is about one-fifth of the volume of the bricks.

English bond in brick-work is considered the strongest. It consists in laying entire courses of headers and stretchers periodically; the proportion here shown is one course of headers to two of stretchers.

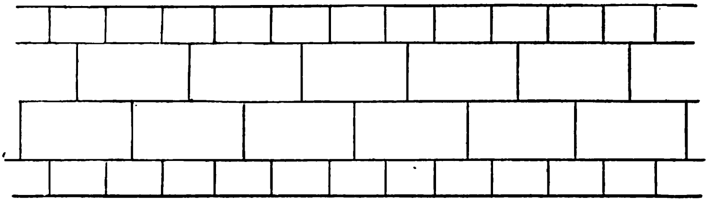


Illustration 10.

In ordinary walls it is usual to lay one course of headers to four of stretchers. Flemish bond in brick-work is a header and stretcher laid in each course; thus:

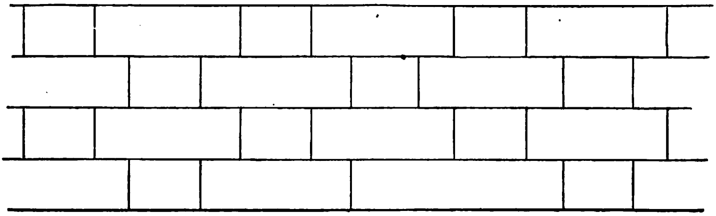


Illustration 11.

This presents a very neat appearance, but it is not considered as strong, where a question of strength arises, as the English bond.

In building a factory chimney the longitudinal tenacity is more important than the transverse; and it is best, in cases of this kind, to have four stretchers to one of headers.

Brick-work is estimated by the thousand, and also by the cubic feet. Walls vary slightly in thickness, owing to the sizes of the brick; but the superficial quantity is the same.

TABLE OF BRICK–WORK.

8 or 9	inch	wall,	1	brick	thick,	14	bricks	to the	superficial	foot.
12 or 13	"	"	1½	"	"	21	"	"	"	"
16 or 18	"	"	2	"	"	28	"	"	"	"
20 or 22	"	"	2½	"	"	35	"	"	"	"

The best Philadelphia and Baltimore brick are eight and one-half inches long by four and one-quarter inches wide, by two and one-half inches thick.

The Baltimore front and wall brick are the same size as the Philadelphia. The average size New York brick is eight inches in length, four inches wide, and two and one-quarter inches thick, and are mostly made up the North River. Inferior grades of brick are made eight inches long, three and one-half wide, and two and one-half thick, and some of them sold in the New York market are unfit for sound walls. The Croton North River brick measures eight inches by three and three-quarters wide, by two and one-quarter inches thick; average when laid, four courses, including mortar, to ten inches. The very handsome white brick, for ornamental purposes, from Perth Amboy, is eight and one-quarter inches long, four and one-eighth inches wide, two and one-quarter inches thick. The Trenton, New Jersey, brick is eight and three-eighths inches long, four inches wide, and two and three-eighths inches thick. The Enameled-faced bricks made in New Jersey are buff, brown, black, cream and blue in color, and are eight inches long, four inches wide, and two and one-half inches thick. Hollow burned brick, used for hollow brick walls and inside firring of various sizes, are:

Single,	8	inches	long,	3⅝	inches	wide,	by	2¼	inches	thick ;
Double,	8	“	“	7½	“	“	“	4½	“	“
Treble,	8	“	“	7¼	“	“	“	7¼	“	“

Hollow arch brick are about 7¼ x 7¼, beveled for arches and various sizes.

In the Use of Stone for Building Purposes and Walls generally, it is important that the architect and builder should have a fair knowledge of rocks and the quarries from whence the stones are obtained; hence, there is herewith given some concise definitions of oxides, and the formation of various Rocks found and in use for Building purposes generally.

Lime is oxide of calcium.

Soda is oxide of sodium.

Silica or *Quartz* is oxide of silicum.

Alumina is oxide of aluminum.

Air contains twenty-three per cent. of oxygen, the rest is nitrogen and carbonic acid.

Rocks :—Feldspar is a double silicate of alumnia and an alkali; there are many varieties, and it is nearly as hard as quartz.

Hornblende is a double silicate of iron and alumina; it is slaty in structure, but generally a mass of prismatic crystals, sometimes fibrous, but not elastic. Among the varieties is sometimes *asbestos; which is pulverized and used as fire-proof paint, and woven into felt for roofing, etc.*

Syenite is hornblendic granite; it has the same feldspar and quartz as granite, but has hornblende instead of mica; it resembles the the mica granites very close, but does not split well.

Granite consists of feldspar, quartz and mica; it is the most granular of all rocks. The quartz is usually white and glassy. Feldspar is light red or yellowish white, and the mica is in little packages or sheets of any color to black. Immense quarries of all shades of granite are found throughout Maryland, also in Virginia, New Hampshire, Massachusetts, and in most of the United States. The Equitable Building, Broadway, New York, is built of Concord Granite; it is an excellent stone building. The Staats Zeitung Building, opposite the City Hall, N. Y., is built of two kinds of Granite; the first story is Quincy Granite; the other stories are of Concord. The Western Union Building, N. Y., is built of a light grey granite from the vicinity of Richmond, Va. (the brick on the fronts are from Baltimore).

Gneiss is a form of stratified granite, obscure and irregular in strata; it is somewhat crystaline; it is a metamorphic rock, not valuable generally for building purposes.

Schists are rocks composed of finer materials than the gneiss. Schists are stratified; the strata generally lays flat. This is also a metamorphic rock.

Slates are the finer grained schists. The clay slate is the finest grained of the slate; the talcose slate is the most metalliferous, the mica next, and the clay slate next.

Marble is the purest form of carbonate of lime (except stalactites), and is an earlier formation of limestone, with a pressure which retained the carbonic acid. The Marble residence erected for A. T. Stewart, in New York, is built of selected White Marble from the Westchester County quarries of N. Y. The Mutual Life Insurance Company Building, of Boston, Mass., is built of Marble from the quarries of Westchester County, N. Y. The Drexel Building is built of Connecticut Marble.

Calcite, or *Carbonate of Lime*, are transparent crystals when pure, but changes color with impurities, becoming white marble, or colored blue, yellow or grey limestones.

Gypsum, or *Sulphate of Lime*, *i. e.*, the result of the action of the oxide of sulphur on oxide of calcium, is known as Plaster of Paris.

Oxide of Iron is a rock-building mineral, and is diffused through nearly all rocks; makes great rock masses by itself; oxide of iron in limestone or sandstone injure it for dressed stone surfaces.

Talc is a silicate of magnesia with some potash and iron greasy of touch; allied species are soapstone and serpentine.

Serpentine is a greenish melted rock; it is almost entirely made of talc. Some varieties are used for fine masonry.

Green Stone is composed of feldspar and hornblende; it is granular and very tough and hard; it is the metamorphic form of the igneous rock, diorite.

Diorite is hornblende and feldspar; is greyish white sometimes with speckles of dark green spots.

Basalt consists of feldspar, augite and chrysolite, and often with iron in small proportions; it is dark grey or green to black. A basalt stone of dark color is extensively quarried in New Jersey for rough walls and foundations.

Dolerite is basalt with chrysolite left out, and is not so often green like basalt.

White Trap is a pure feldspar; white trap is used extensively in New York for paving stones.

Sandstone. A Rock made from sand agglutinated. Compact sandstones are used, for fronts to buildings; for instance, Belleville, N. J., brown stone, or Connecticut brown stone, etc.; Friable Sandstone is not suitable for constructive purposes; Ferruginous sandstone; this becomes discolored in spots; Concretionary sandstone; Micaceous sandstone, is sandstone with scales of mica. Argillaceous sandstone contains much clay with sand; also called Shaly stone when thin and laminated. Marly sandstone contains carbonate of lime, so as to effervesce when treated with weak acid.

Veins are the crevices and fissures of the rocks, filled with other substances than the rocks.

Hydraulic Lime is any combination of lime with very silicous clay.

Marl is simply limestone; has been so recently formed that it has not yet become compacted into solid rock.

Extracts have been made from the book of Mr. F. H. Smith, of some terms.

Pozzoulana Tufa is an earthy rock, not very hard, made from volcanic cinder, more or less decomposed, usually of a yellowish brown color; it is used for hydraulic cement.

Sand is comminutive or pulverized rock of any kind; but common sand is mainly quartz, or quartz and feldspar.

Pink and Red Granites—The color occurs in feldspar. When used in buildings they produce a fine effect, and can be highly polished. Also, when it is the intention to use a stone without cutting the surfaces, and only squared with a tooled face, and where the edges are axed, it is very fine in effect. Dark-red granite, equal to the Scotch, is now quarried in Nova Scotia.

The within list gives the average kind of rocks and sandstones of the earth used in construction, etc. There are many varieties, not necessary to name here, with names peculiar to the location of quarries, and varieties with traces of metal, etc.

In returning to the subject of the materials of walls, I will give some suggestions on stone walls for dwellings, where the outside walls are exposed.

A Stone House properly built is undoubtedly the most expensive structure that can be erected. It produces a fine, substantial and showy external appearance; and creeping vines may be grown at inner angles to produce that picturesque and homelike appearance that is seldom seen on other structures. But such a house is not any warmer in winter, or cooler in summer, than a brick one.

The proper construction for the walls of a stone dwelling, is to have the beds and joints of squared or drafted stone. This is termed squared random work. This enables the mason to more fully fill the joints with mortar.

The walls of a stone house should not be constructed of rough rubble-work, as it is impossible to fill completely all the joints with mortar; and hence in a driving storm of rain it will be forced through the crevices, and produce dampness; quarry-faced stone at the least should be used.

A stone house can be constructed either with hollow or solid walls, or the inside lined with hollow brick.

When hollow walls are built, the outside wall should be not less than sixteen inches thick of stone, with a three-inch space inside, and backed up with four inches of brickwork, and bond the inside and outside wall with iron ties or clamp anchors. Where binders or headers of brick are used dampness will usually penetrate. Hollow walls to be effectual, must have outside and inside work separate from each other.

When solid walls are used, it is necessary for all out side walls to be firred on the inside with strips, and to be lathed for the plastering.

Flags or slabs of stone that are thin make poor footings, where, in proportion to the weight of the superstructure, they are carried out to get a greater bearing. When this is done, the stone will often rend, and become displaced, through the whole batter, as may be seen in figure.

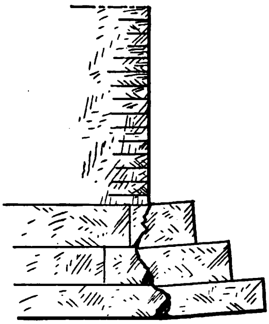


Illustration 12.

In building large masses of work, such as the abutments of bridges and the like, the proportionate increase of bearing surface obtained by the projections of the footings is very slight, and there is a great risk of the latter being broken off by the settlement of the body of the work. It is therefore usual in these cases to give very little projections to the footing courses, and to bring up the work with a battering face, or with a succession of very slight set offs. See figure.

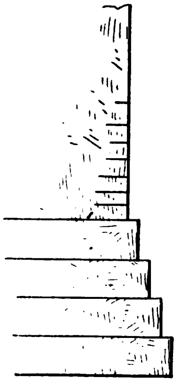


Illustration 13.

Footings of undressed rubble built in common mortar are not safe; for in case of the compression of the mortar, it is sure to displace the superstructure.

A safe way of using rubble is to break it up tolerably small, and lay it in the trenches without mortar, as it forms a hard unyielding bottom so long as it is prevented from spreading laterally by the pressure of the ground.

Where the building is small rubble, the best way to proceed is to lay the foundations with cement mortar, so that the whole will form a solid mass. In this case the size and shape of the stone is not important.

In building with brick, the great point to be attended to in the footing courses is to keep the back joints as far as possible from the face of the work; and in ordinary cases the best plan is to lay the footings in single courses—the outside of the work being laid, all headers and no course projecting more than one-quarter of the length of the brick above it, except in eight or nine inch walls. Where more bond is required in the work, the courses must be doubled, the heading course above and the stretching course below. See figures.

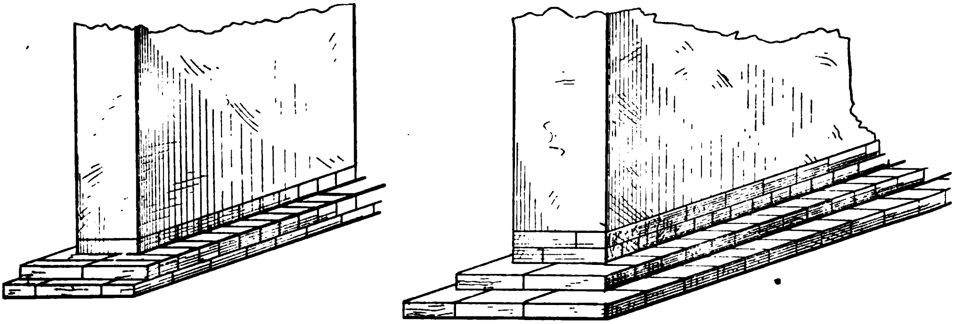


ILLUSTRATION 14.

Bricks used in trenches and for footings should be the hardest and firmest. It is desirable that the bottom course should in all cases be a double one.

Proper care and judgment should be exercised upon laying the footing courses of any building, as upon them depends much of the stability of the work.

If any rents or interstices are left in the beds of the masonry, or if the materials themselves are unsound or badly put together, such carelessness will show sooner or later, and then there is no remedy; and if one, that attended with great expense.

Inverted Arches used in the footings and foundation walls of superstructures, should have properly considered abutments for them on both sides. If used at the extreme angles of building (see figure), the effect of any settlement will move the corner pier from a plumb or vertical position to the dotted line shown on figure. The execution of these inverted arches should be very perfect, as any settlement in them has a bad effect on the piers, and consequently give opportunity for that fracture which their presence was intended to obviate.

Inverted arches may be constructed with facility by moulding their backs in the ground to be occupied by them;

and this may be very exactly done by pressing down an inverted centering, removing it, and smoothing down the cement or concrete. The setting of the brick or stone then

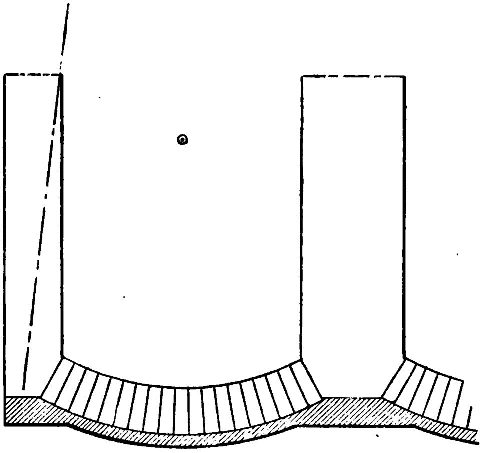


ILLUSTRATION 15.

becomes an easy matter. Besides foundations for buildings, inverted arches are constantly used in constructing sewers.

The parabolic form is the best for such arches; it is the surest for resisting thrust, and besides this it has the advantage of not having to be sunk in the ground so deep.

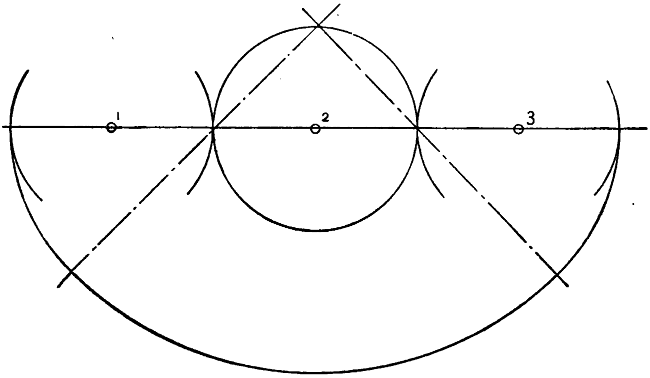


ILLUSTRATION 16.

Illustration 16 represents the method of getting the lines for centering for a curve approaching the parabolic or elliptic, and is greatly used where half circles cannot be used.

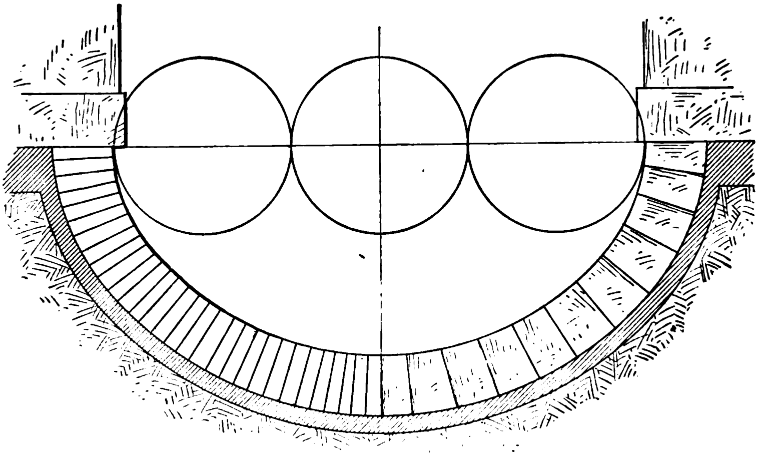


Illustration 17.

It is sometimes required to span spaces where there is a soft bottom, when inverted arches are used. In cases of that kind a form of construction, as shown in figure, may be used.

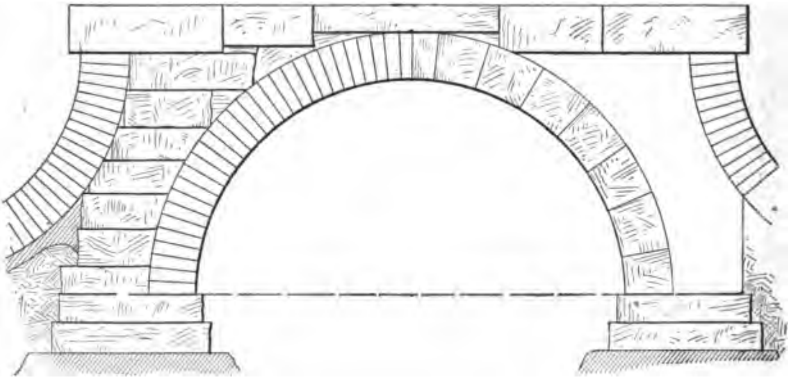


Illustration 18. **For large spans use the Elliptic Arch.**

In cases where the ground is soft the expense of spreading out solid work to the requisite extent, renders it necessary to use some cheaper method for the footings. Three methods may be mentioned.

First. To put in a wide footing course of timber, using timber that will sustain heavy shearing strains; and then it is best to char it.

Second. To put down a layer of concrete, using one of the various hydraulic limes in its composition. It requires the concrete to be spread over the footings to a breadth equal to the bearing surface of the stratum below the footings.

Third. To build upon a layer of sand or gravelly deposit, with trenches dug to receive it, which pressing against the sides, as well as the bottom, distribute the weight of the structure over a large resisting surface.

Where it is the intention to erect buildings on soft ground, and a large bearing surface can be obtained, timber may be used with great advantage, provided the timber can be prevented from decaying. Some char the timber, and others give it a coat of asphaltum. If the ground is wet, and the timber is good, there is little to fear; but when exposed to wet and dryness, you cannot depend on unprepared timber. The kyanizing and creosoting process was used some fifteen years ago, but seldom done now, as most localities have some method of their own, such as hereinbefore mentioned.

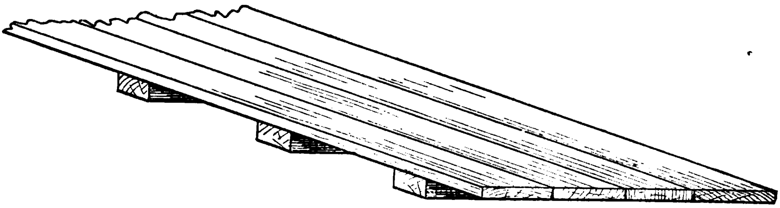


ILLUSTRATION 19.

The best method of using planks under walls is to cut them in short lengths, which should be placed across the foundations, and tied by longitudinal plank, laid to the width of the bottom course of the walls, and spiked to the bottom planking. See Illustration 19.

A common method of planking foundations is shown in Illustration 20. The space under the planking intended to be rammed. After this, bed the sleepers of timber in concrete, and fill the spaces between them flush with concrete to the top, so the planking may rest on a solid level surface.

This same method is used under basement or cellar floors, to prevent rats and mice from getting in and making nests.

Mr. Dobson, C. E., who has devoted considerable time and attention to foundations, has been consulted in some instances.

Before proceeding further with footings and foundations, it is important for the architect and builder to have some knowledge of the weight of material used in the superstructure or building to be supported on these foundation walls, and for this purpose we herein present the following tables:

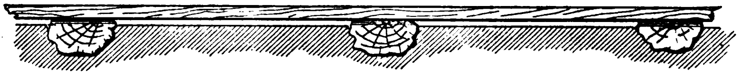


Illustration 20.

TABLE OF WEIGHT OF TIMBERS, DRY.

Green timber usually weighs one-third more than dry.

Maple	49	pounds to a cubic foot.
White Oak	51	" " " "
Southern Yellow Pine	45	" " " "
Northern Yellow Pine	35	" " " "
White Pine	30	" " " "
Spruce	25	" " " "
Hemlock	25	" " " "
Chestnut	41	" " " "
Cherry	42	" " " "
Ash	38	" " " "

WEIGHT OF BUILDING STONES, ETC., PER CUBIC FOOT.

Granite or Limestone, dressed	165	lbs. to 1 cubic foot.
Masonry of Granite, well scabbled, mortar rubble, one-fifth of mass—mortar.	154	" " " "
Brickwork, mortar included	115	" " " "
Marble	168	" " " "
Hardened Mortar (1 to 4 and 1 to 9)—Sand weighs	103	" " " "
Serpentine Stone	162	" " " "
Sand (Sand is retentive of moisture, and varies greatly in weight)	90 to 120	" " " "
Water	62	" " " "

Clay (dry)	119	lbs. to 1 cubic foot.
Hydraulic Rosendale Cement, American	56	“ “ “ “
Teil Hydraulic Lime	45	“ “ “ “
Common Loam Earth, slightly moist	75	“ “ “ “
Common Loam Earth, slightly moist, and firm sand, moderately packed	90 to 102	“ “ “ “
Gneiss—166 lbs. cubic foot, loose in piles	98	“ “ “ “
Hornblendic Gneiss	175	“ “ “ “

CHAPTER V.

Arches in Walls.—At the springing line of arch to walls it is well to provide stone skewbacks or corbelling, represented by figure.

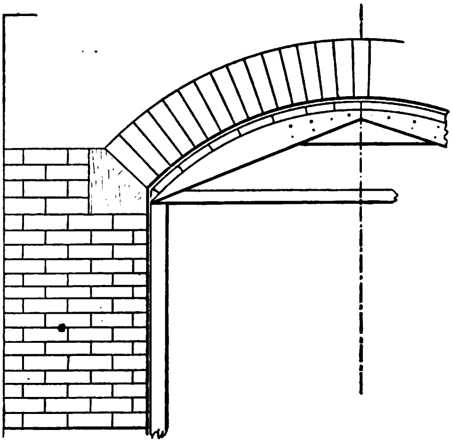


ILLUSTRATION 21.

By this method the construction of the arch does not encroach upon the piers.

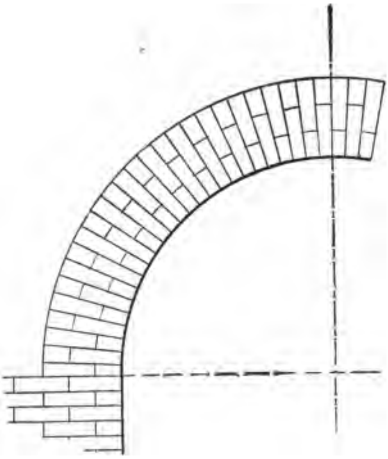


ILLUSTRATION 22.

Construction of Arches.—In constructing brick arches it is always best to specify arch brick, as they form better voussoirs than the parallel brick, and do not have to depend so much on the cement or mortar. Arches over piers or thick walls, which support a superstructure or several stories, should be constructed as shown in illustration 22, which bond the arch brick.

Chimney Walls and Building the same.—A broad, deep and substantial foundation is necessary below the action of frost, and will not settle. If it becomes a part of the walls, the footings should be made proportionately broad to sustain the weight above.

It should be straight and smooth, having *no* angles or jogs if possible. No woodwork should be built on to the chimney, but leave a space once around it.

The walls of chimneys when built of six inches thick, having the bricks set on edge inside, and bond with brick laid every four or five courses, is nearly as safe as an eight inch thick wall. Where four inch walls are used around flues to chimneys, it is always best to carry the smoke-pipe into a vitriolized clay pipe, and this pipe to run ten to twelve feet above the smoke hole.

An opening at the bottom of all flues should be provided in stoves; it is usual to have light iron frames and sheet iron doors, so that the soot may be removed at any time.

Chimneys should be smoothly plastered with mortar mixed with lime, with small proportion of plaster of Paris or cement.

Proportion for Brick Chimneys—for manufactories using from twenty to thirty horse-power engines.

The diameter at base should be not less than one-tenth of the height.

The footings from one and one-half to twice the diameter (or one side) of base.

Batter of chimney, three-sixteenths inch; or, three-eighths inch; or, one-half inch; to one foot in height.

Thickness of brick wall at top, twelve inches; and twenty-five feet below.

From twenty-five to fifty feet below top of chimney, sixteen to twenty inches thick.

From fifty to seventy-five feet below top, twenty-four inches to two feet, four inches thick.

Such a chimney would average from six feet to six feet eight inches square at base, with twenty inches to two feet square flue.

The batter of chimneys are reduced at top from one-quarter to one-third of bottom diameter or side of square.

From one-sixth to one-eighth of the height of chimney the walls should be perpendicular, and when desired at starting line of batter, use a belt course of stone or brick.

The top of chimney should always be capped with stone or iron caps.

All brick laid on inside or outside of flue should batter evenly ; they should be regular in size, sound and hard-burned, and laid with even joints.

It is sometimes necessary to remove dampness in chimney flues by building a fire in the base, with light fuel, before building the engine fires.

A chimney for any ordinary boiler should be twenty to twenty-five feet high. The location of a chimney governs the height; *i. e.*, in the vicinity of houses it should not be less than five feet above their roofs; in low-lands it is necessary to carry the top above the downward currents.

Masons' and Stone-Cutters' Tools.—The names given tools for this purpose vary according to locality, but the following names for some tools are common over the United States:

The Face Hammer. The head has one flat end, and one wedge shaped edge for roughly shaping stones from the quarry; the head is about ten inches long.

The Double Face Hammer weighs from twenty to thirty pounds, and is used the same as the other, but for the roughest work.

The Pick Hammer is used for rough dressing on sandstone or limestone; it is wedge shaped on both edges, with handle in the centre.

The Axe Hammer has also two wedge edges for cutting;

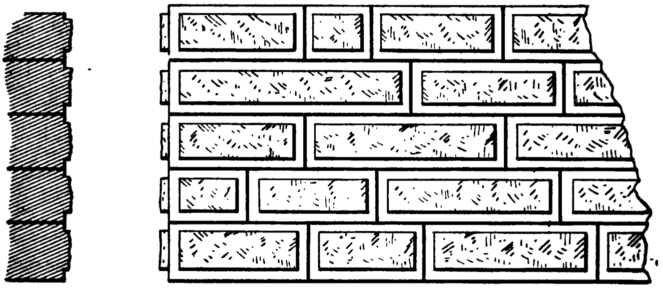
it is ten inches long and four inches on each edge. It is used in reducing faces and joints to a level, and for axing a draft around the edges of stone.

The Patent Hammer is a double headed tool, and holds a set of wide, thin chisels. The chisels are held in position with bolts on ends of head, etc. There is also a variety of tools that require only the use of one hand: The hand hammer, which weighs from two to five pounds, is used in pointing, drilling holes, and work on hard rock with chisels; the mallet is used where sandstone or limestone is to be cut; the chisels used are known as tooth chisels, splitting chisels, plug chisels for splitting rocks, etc. Stone carvers have a variety of tools, for which there are no names in particular, and which are varied according to their work.

In specifying masonry, whether patent hammered, axed, bush hammered, etc., it is best to have each estimator to supply a sample cube of four to six inches of stone, all from the same stone, and of the style of work proposed to be done.

Stone Cutting.—All stones used in buildings are as follows:

Rough stones that are used as they come from the quarry.
Stones roughly squared and dressed.
Stones accurately squared and finely dressed.



ILLUSTRATIONS 23 AND 24.
Drafted or Axed Edge and Pointed Quarry-faced Ashlar.

Quarry-Faced Stones are those whose faces are left the same as they come from the quarry, similar to illustrations 27, 28 and 29.

Drafted Stones are those on which the face is surrounded with a chisel draft, the inner space left rough.

Squared Stones; all stones that are roughly squared and dressed on beds and joints, and where the thickness of joint is from one-half to one inch thick, as the case may be.

Cut Stones.—This is for all stones dressed true and square, with dressed bed and joints; the edges may be drafted and the face left rough; bush or patent hammered work on some sandstones seems to loosen the stone, and in course of time it will shell off.

Ashlar or broken ashlar masonry may have cut faces with any of the various tools, *i. e.*, bush hammered, patent hammered, fine pointed, etc., or rubbed work; it is always known as cut work unless particularly described. (See illustrations 23 and 24.)

Dry Area of Brick or Rubble.—Dry areas around buildings are sometimes made in the following manner, and covered with flat stone, or arched with brick or rubble stone (see illustration):

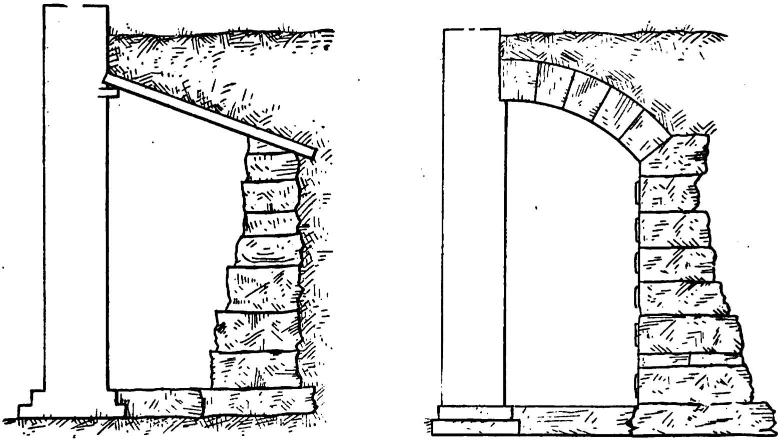


ILLUSTRATION 25.

The bottom to have a descent to the drain, and paved with brick laid with hot pitch, or as the case may be.

Rubble Footings for ordinary walls are usually built as shown in figure 26, of rough stone, bedded in mortar composed of one-third well-burnt stone lime, and two-thirds clean sharp sand; *A* representing the footing.

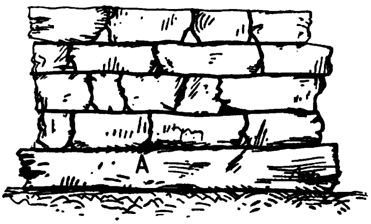


Illustration 26.—Rubble Footings.

Bond Rubble.—Provide a sufficiency of stones for bonding in longer lengths than the size of the rubble stone, which is used or bedded as found in the quarry. All interstices should be filled with small stone and mortar; and at the height of eighteen inches to twenty-four inches the work should be routed with new made (mortar) grouting and used at once.

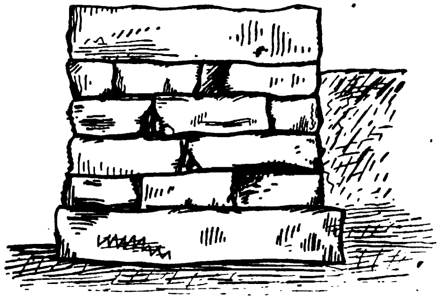


Illustration 27.—Bond Rubble.

Random Coursed Stone Work.—Figure 28 represents neat faced and pointed random coursed work; the stones to be hammer dressed to a fair surface, or tool pointed; and neat joints and well pointed with mortar.

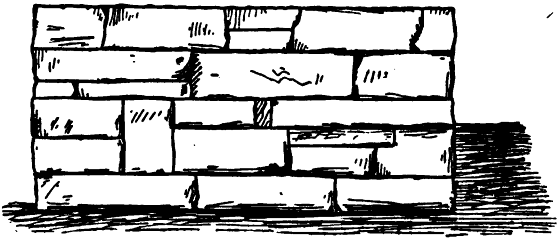


Illustration 28.—Random Course.

Regular Faced and Squared Stone Work.—This is usually built above ground, for basement or exterior walls, and in areas, and is finished in neat and regular coursed work, no course more than sixteen inches or less than eight inches, as the case may be; it is hammered and dressed to a fair surface, and the joints are close and true.

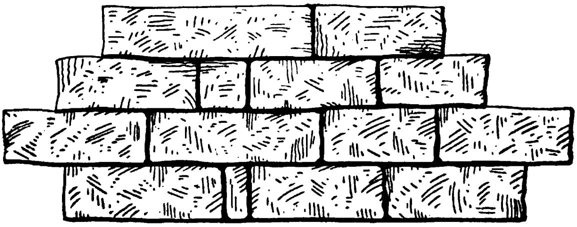


ILLUSTRATION 29.—Quarry Faced.

Trimmed and Coursed Ashlar Facing.—The face of walls to the exterior of buildings are usually trimmed with ashlar facing of stone; the joints may be all square and close, or have moulded or chamfered edges with horizontal beveled joints.

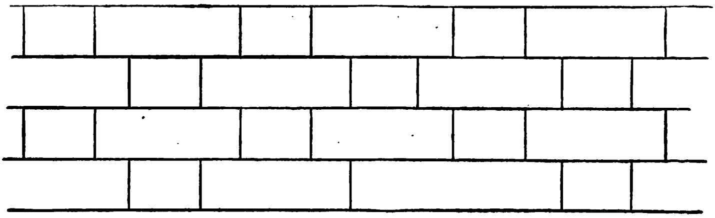


ILLUSTRATION 30.

The following list gives some of the stones used for the exterior of buildings for facings or ashlar work, in New York city and surroundings.

Dorchester, New Brunswick, Green Stone.—Iron sometimes appears on the surface if not selected.

Berea Stone.—Blue cast, grey; very good; produces fine effect in combination with brick.

Wyoming Valley Blue Stone, Penn.—Of a close texture; used in front ashlar, trimmings, etc.; not good for flags.

Connecticut Free or Brown Stone is not in use now as much as formerly.

Blue Grey Stone, from Cincinnati, well spoken of.

Blue Stone Flags come from Hastings, on the North River.

Granite.—Greater part has come from Concord, New Hampshire, but now granites from Massachusetts, Maine, Maryland and Virginia are coming into use.

Marble.—The most of the marble used in New York comes from the quarries of Westchester County. The marble of the R. C. Cathedral was quarried at Pleasantville, New York.

Canaan Marble, of Conn., is used some, and also

Vermont White Marble.

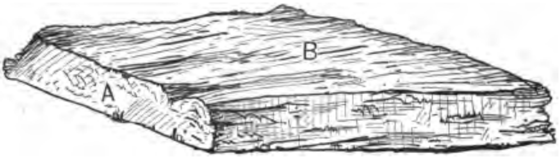


ILLUSTRATION 31.

Figure 31 represents the faces of stone before being dressed; *A*, the natural face; *B*, bed of the stone.

One of the most beautiful building stones for residences, churches, etc., is the serpentine stone found in Chester County, Penn. It is known to preserve its freshness of color, which is a pale green, varied, in some specimens, by darker shades of the same color. It is valuable as a building material, and affords a pleasing variation from the monotonous effect of rows of brick or brown stone buildings.

It sometimes occurs in building walls that an opening is required of a certain height, where a semi-circular arch cannot be used, and yet the wall has to sustain an immense load. In a case of that kind it is best, where brick has to be used, to make the construction as shown by Illustration 32.

A represents the opening above segment arch; *B* the tier of beams to be supported; and *C* the semi-circular arch above (filled in) to sustain the total load.

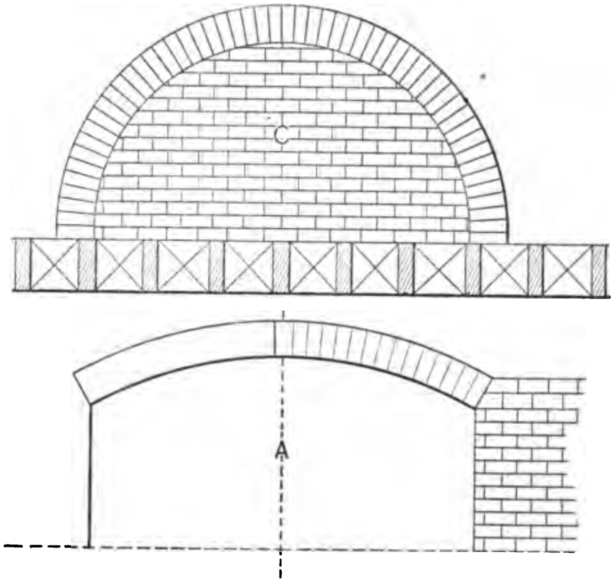


ILLUSTRATION 32.

Dampness in Foundation and Cellar Walls.—In dwellings that are isolated, to avoid dampness from penetrating the basement or cellar walls that are below the line of earth, architects sometimes specify that the outside of the walls be cemented from the footings to the base-board of framework, or base line of stone moulding, and in some instances stop the cement four to six inches below line of earth. Then excavate the earth around the structure to the distance of two feet from wall, and to a depth of sixteen to twenty inches, and at an angle of ten degrees lay one course of brick flat up to wall line, and cover with a coat of cement, as shown on Illustration 33.

Before this is done, it is necessary to fill in earth and settle it around the walls. After this is done, allow it to set perfect before covering with earth. As the foregoing method interferes with flowers and grasses up to line of wall, here is another method (see illustration 34).

After the wall has been built and cemented on the outside (Rosendale cement is good enough), excavate the earth

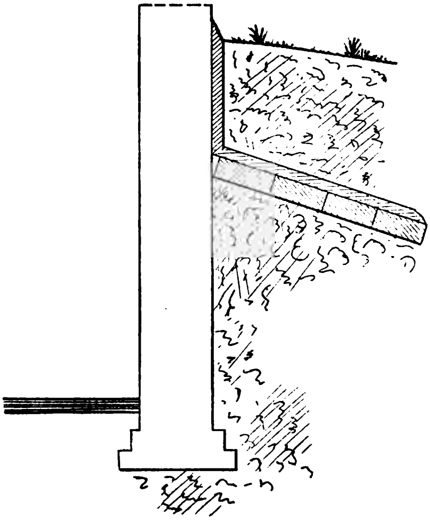


Illustration 33.

on the outside to line of footings, fill with firm earth to top of footings, and grade the excavation to a proper descent to

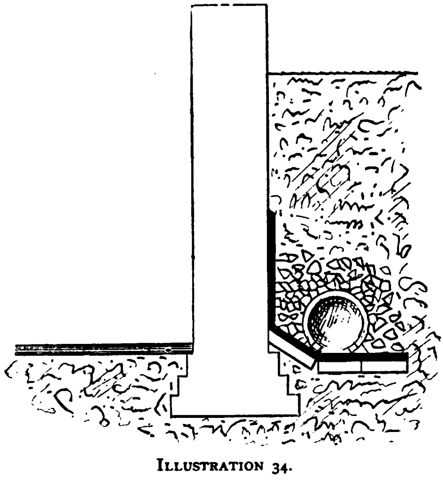


Illustration 34.

carry the water to sewer in a drain-pipe laid on top of a course of bricks cemented, and on top of this put loosely broken stone, and cover the whole over with earth when it is dry. Where there is a clay bottom and much moisture, even this will not prevent dampness from arising in the cellar. To overcome this, use the method shown in illustration 33 on the outside, and that of 34 on the inside.

Prepare the cellar bottom, and lay say three to four inches of sand, rolled down firm and even; on top of this put a coat of cement, one to one a half inches thick, over the whole surface of the cellar; and lay off around the cellar walls in the cement flat gutters of slight descent to the sewer or waste-pipe.

There are clay soils sufficiently solid for walls of dwelling houses. But the clay in wet seasons retains so much moisture that it does not seem to be carried away into the earth, but rises and penetrates through the cellar bottom, and keeps the cellar damp nearly all the time. This is a serious difficulty to overcome; but I have known the following method to be carried out with success:

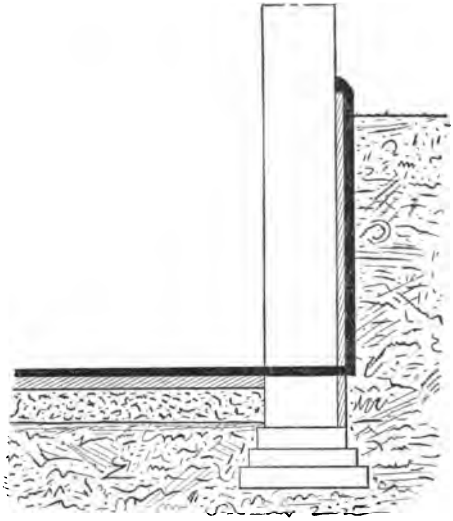


Illustration 35.

Excavate the foundations to the depth required to put in the footings, and in the cellar bottom four to five inches of sand rolled hard, on top of which lay a coat of cement, not less than one inch thick; and when this is as dry as possible, put a coat of asphaltum over the whole surface up to the lines of the inside walls, and through one course of brickwork around the whole structure, care being taken to cement the outside wall, and coat it with asphaltum, same as the cellar floor. This is the best course to pursue where there is no chance for a drain.

Another Method to Secure a Dry Cellar.—Perform such leveling to the cellar bottom that may be required, spread over this sand to the depth of three to five inches, and roll or pack firm, on top of this; cover the whole surface with one inch thickness of cement mortar, Rosendale or American brands, carry it well against the inside of the outer walls. Coat the outside walls with cement one-half to three-quarters of one inch thick in the same manner up to dry line.

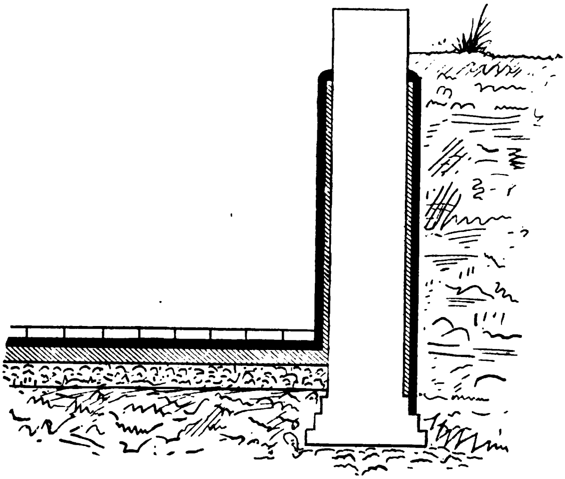


Illustration 36.

Then on top of this lay a coating of asphaltum, tar and sand, applied hot; carry the asphaltum through the wall (this should be provided for when foundation walls are being built), and coat the outside wall to dry line with hot asphalt. When the asphalt is sufficiently dry to walk on, dip heated brick into asphalt and tar, and lay closely the whole surface with brickwork. When it is not possible to carry the asphalt through the wall to the outside, carry it up on the cement on inside.

The best mixture of asphalt is to mix with the asphalt ten per cent. of coal tar, and twenty-five per cent. of sand; and use while hot to form a cement for bedding brick for damp cellar bottoms.

Sylvester's Process for Repelling Moisture from External Walls.—The proportions are for the first: Mix three-quarters of a pound castile soap with one gallon water; second, mix one-half pound alum with four gallons water. These substances to be perfectly dissolved. The walls should be clean and dry, and the temperature not less than 50° Fah. when the composition is applied.

Put the soap wash on when boiling hot with a flat brush, and do not work to a froth. Let it dry twenty-four hours, or be perfectly dry. Then put on the alum wash at about 65° Fah. for the mixture, and should dry perfectly before putting on the soap wash; and this is to be repeated alternately until the wall is impervious to water. The alum and soap forms an insoluble compound.

CHAPTER VI.

Front Vaults.—An important part of construction to store buildings in our large cities is the excavation and building of vaults under the streets, or under the sidewalk and area. See Abstract of Laws in reference to vaults, chapter iii.

These vaults are usually lighted by setting thick glass in iron frames over the area part—the best are those made by J. B. Cornell—and the sidewalk is covered with arched brickwork, and on top of this stone flags, or covered with large flags of stone, resting on a girder or beam supported by columns where necessary. The best stone is the North River bluestone in use here, and is generally ten inches thick. Where

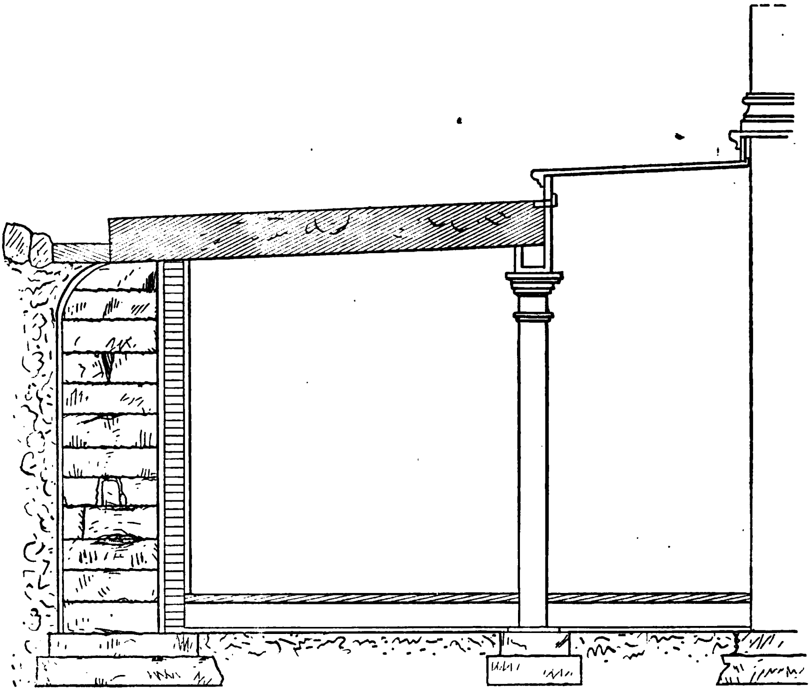


ILLUSTRATION 37.

granite has been used for the purpose it wears so very smooth as to become objectionable. The joints of the stone are caulked with oakum, and filled with pitch and cement. See illustration 37.

The top of walls (*A*) are usually coated with asphalt cement. The outside retaining wall is usually two feet six inches to three feet thick, with a hollow space of two or three inches, and an inside eight-inch wall.

Illustration 38 represents the construction of an area where the walls and vault are extended out under the street beyond the curb. For this arrangement there is generally required a special permit.

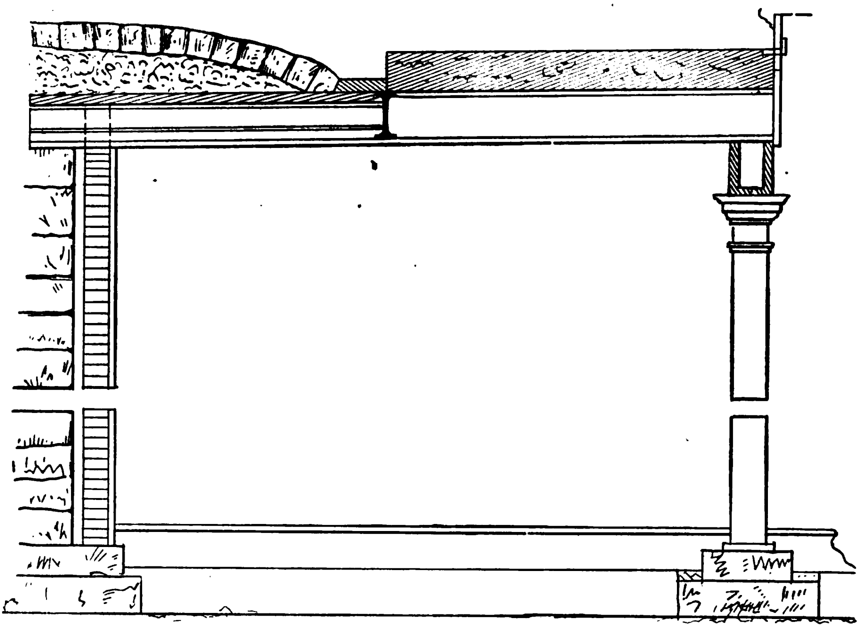


ILLUSTRATION 38.

Vaults under sidewalks are sometimes carried to the depth of twenty-five feet below line of curb, and make two stories extending under sidewalk; the outside retaining-wall is usually of stone.

TABLE OF STRENGTH OF STONE FOR VAULTS, PLATFORMS, GALLERIES, BAY-WINDOWS AND OTHER PURPOSES.

Transverse Strength of Flagging.—*W*, width of stone in inches; *T*, thickness of stone in inches; *D*, distance between bearing in inches.

The Breaking Load in Tons of 2000 *lbs. for a Load on the Centre of Surface.*

$$\frac{W \times T^2}{D} \times$$

Quincy Granite	.622
Black Granite	.430
Blue Stone Flagging	.744
Belleville, New Jersey, Freestone	.312
Dorchester Free Stone	.264
Caen	.144
Ambigny	.216

Thus a blue stone flag, 100 inches wide, 6 inches thick, resting on a bearing, or on beams, 72 inches to centres, would be broken by a load resting midway between the beams or support $\frac{100 \times 6^2}{72} \times .744 = 37.20$ tons, breaking load.

It is best in using these tables not to exceed a working load of one-quarter to one-sixth the breaking load. Over vaults to warehouses allow a load of 600 pounds per square foot, and 500 pounds per square foot for stores.

TABLE OF EXPERIMENTS ON BRICK.

BRICKS.	*Fractured in lbs.*	*Crushed in lbs.*	*Fractured, sq. in.*	*Crushed sq. in.*
Common Hard Brick	20,000	46,000	625	1435
" "	12,000	30,000	375	935
Dry Pressed Staten Island	20,000	50,000	625	1562
Philadelphia (whole)	15,000	60,000	468	1875
" (half)	20,000	54,000	625	3375
Massachusetts Flint	50,000	not crushed	1562	....
Colabargh	40,000	60,000	1250	1875
Firebrick	......	20,000	....	625
New Jersey, unburnt	13,000	15,000	406	468
Best Hard North River Pavers (half)	38,000	55,000	2375	3437
North River whole Brick not injured at	......	60,000	....	....

Adamantine Press Cis-brick, crushed at 90,000 lbs., being at the rate of 2,800 lbs. on the square inch.

RULES OR TABLE FOR CALCULATING THE WEIGHT OF MATERIALS IN BUILDINGS.

Calculate the weight of wall per superficial foot of surface, and deduct only one-half of window openings.

8-inch brick wall, weight per foot	77	pounds.
12 " " " " " "	115	"
16 " " " " " "	153	"
20 " " " " " "	192	"
24 " " " " " "	230	"
Brown Stone, 4 inches thick	57	"
" " 8 " "	114	"
" " 12 " "	170	"
Granite, per foot	166	"
White Marble	168	"

NEW YORK LAW IN REFERENCE TO LOAD ON FLOORS.

Hardware Store,	weight on square foot floor surface	350 to 600 lbs.
Flour Store,	" " " "	350 "
Dry Goods Store,	" " " "	310 "
Public Assemblies	" " " "	180 "
Tenement House,	" " " "	100 "
Roofs,	" " " "	90 "

After making calculations of loads in ten dry goods stores, they were found not to be loaded to exceed 180 pounds per square foot on the basement or first and second stories, and much less above.

Mensuration of Superfices.—Simple rules for calculating superficial surfaces of different shapes:

Triangle—Multiply base by perpendicular and divide by 2.

Equilateral Triangle—Square of any side by .433.

Trapezoid—Two parallel sides by perpendicular distance between them; divide by 2.

Parallelogram—Base by perpendicular.

Trapezium—Diagonal by one-half sum of perpendicular circle.

Circle—Diameter 2 by .7854.

Circle—Circumference by radius, divided by 2.

Ellipse—Transverse axis by conjugate axis by .7854.

Cylinder—Length by diameter by $3\frac{1}{7}$.

Previous to the establishment of a Department for the Inspection of Buildings in the city of New York, every contractor to considerable extent engineered construction to suit himself, and at the time J. M. Macgregor was Superintendent of the Inspection of Buildings in the city of New York, and at the beginning of the term of his office, he had innumerable prejudices to overcome, endless work, and to contend with the obstinacy of builders. Walls had been constructed of soil and refuse lime; ordinary 8-inch walls of inferior brick were built for party walls to sustain the ends of beams on each side for floors, and every variety of insufficient construction. He succeeded in having passed good and sufficient laws relative to party walls and to the construction of buildings, which gave greater security to all classes of structures. I have known him to have to explain to the party soliciting a permit to build, what kind of foundations should be built, what kind of walls, what kind of timber, stone, brick, and in fact educate large numbers of those about to build what there is required in buildings. Without building laws in large cities, there is but little security for the solidity of structures.

BUILDING LAWS PASSED APRIL, 1871.

Abstract from the Building Laws of the City of New York in reference to Walls, Foundations, etc., now in force.

"SEC. 3. **Depth of Foundation Walls.**—All foundation walls shall be laid not less than four feet below the surface of the earth on a good solid bottom, and in case the nature of the earth should require it, a bottom of driven piles or laid timbers, of sufficient size and thickness, shall be laid to prevent the walls from settling, the top of such pile or timber bottom to be driven or laid below the water line; and all piers, columns, posts, or pillars resting on the earth, shall be set upon a bottom in the same manner as the foundation walls. **Rock bottom.** Whenever in any case the foundation walls or walls of any building that may hereafter be erected, shall be placed on a rock bottom, the said rock shall be graded off level to receive the same. All excavations upon the front or side of any lot adjoining a street shall be properly guarded and protected by the person or persons having charge of the same, so as to prevent the same from being or becoming dangerous to life or limb. **Excavations.** Whenever there shall be any excavation, either of earth or rock, hereafter commenced upon any lot or piece of land in the city of New York, and there shall be any party or other wall wholly or partly on adjoining land, and standing upon or near the boundary line of said lot, if the persons or persons, whose duty it shall be under existing laws to preserve and protect said wall from injury, shall neglect or fail so to do, after having had a notice of twenty-four hours from the Department of Buildings so to do, the Superintendent of Buildings may enter upon the premises, and employ such labor and take such steps as in his judgment may be necessary to make the same safe and secure, or to prevent the same from becoming unsafe or dangerous, at the expense of the person or persons owning said wall or building of which it may be a part, and any person or persons doing the said work, or any part thereof, under and by direction of the said Superintendent, may bring and maintain an action against the owner or owners, or any one of them, of the said wall or building of which it may be a part, for any work done or materials furnished in and about the said premises, in the same manner as if he had been employed to do the said work by the said owner or owners of the said premises.

"SEC. 4. **Base course of foundation walls, piers, columns, etc.** The footing, or base course, under all foundation walls, and under all piers, columns, posts, or pillars resting on the earth, shall be of stone or concrete; and if under a foundation wall, shall be at least twelve inches wider than the bottom width of the said wall; and if under piers, columns, posts, or pillars, shall be at least twelve inches wider on all sides than the bottom width of the said piers, columns, posts, or pillars, and not less than eighteen inches in thickness; and if built of stone, the stones thereof shall not be less than two by three feet and at least eight inches in thickness; and all base stones shall be well bedded and laid edge to edge; and if the walls be built of **isolated piers,** then there must be inverted arches, at least twelve inches thick, turned under and between the piers, or two footing courses of large stone, at least ten inches thick in each course. **Construction of foundation walls.** All foundation walls shall be built of stone or brick, and shall be laid in cement mortar, and if constructed of stone, shall be at least eight inches thicker than the wall next above them, to a depth of sixteen feet below the curb level, and shall be increased four inches in thickness for every additional five feet in depth below the said sixteen feet; and if built of brick, shall be at least four inches thicker than the wall next above them to a depth of sixteen feet below the curb level, and shall be increased four inches in thickness for every additional five feet in depth below the said sixteen feet.

"SEC. 5. **Height, thickness and materials of walls of dwellings.** In all dwelling-houses that may hereafter be erected, not more than fifty-five feet in height, the outside walls shall not be less than twelve inches thick; and if above fifty-five feet in height, and not more than eighty feet in height, the outside walls shall not be less than sixteen inches thick to the top of the second-story beams, provided the same is twenty feet above the curb level, and if not, then to the under side of the third-story beams; and also provided that that portion of the walls twelve inches thick shall not exceed forty feet in height above the said sixteen-inch wall. No party wall in any dwelling-house that may hereafter be erected shall be less than sixteen inches in thickness; and in every dwelling-house hereafter erected more than eighty feet in height, four inches shall be added to the thickness of the walls for every fifteen feet, or part thereof, that is added to the height of the building.

"SEC. 6. **Height, thickness and materials of walls of buildings other than dwellings.** In all buildings, other than dwelling-houses, hereafter to be erected, not more than forty-five feet in height, and not more than twenty-five feet in width, the outside walls shall not be less than twelve inches thick, and the party walls not less than sixteen inches thick; if above forty-five feet, and not more than fifty-five feet in height, the outside and party walls shall not be less than sixteen inches thick; if above fifty-five feet, and not more than seventy feet in height, the outside and party walls shall not be less than twenty inches thick to the height of the second-story beams, and not less than sixteen inches thick from thence to the top; and if above seventy feet, and not more than eighty-five feet in height, the outside and party walls shall not be less than twenty inches thick to the height of the third-story beams, and not less than sixteen inches from thence to the top; and if above eighty-five feet in height, the outside and party walls shall be increased four inches in thickness for every ten feet or part thereof that shall be added to the height of the said wall or walls. **Buildings over 25 feet in width to have partition walls or girders and columns.** In all buildings over twenty-five feet in width, and not having either brick partition walls or girders, supported by columns running from front to rear, the walls shall be increased an additional four inches in thickness, to the same relative thickness in height as required under this section, for every additional ten feet in width of said building, or any portion thereof. It is understood that the amount of materials specified may be used either in piers or buttresses, provided the outside walls between the same shall in no case be less than twelve inches in thickness, to the height of forty feet, and if over that height, then sixteen inches thick; but in no case shall a party wall between the piers or buttresses of a building be less than sixteen inches in thickness. **Corner buildings, thickness of walls.** In all buildings hereafter erected, situated on the the street corner, the bearing wall thereof (that is, the wall on the street upon which the beams rest) shall be four inches thicker in all cases than is otherwise provided for by this act.

"SEC. 7. **Partition walls of buildings over 30 feet in width.** Every building hereafter erected, more than thirty feet in width, except churches, theatres, or other public buildings, shall have one or more brick, stone, or fire-proof partition walls, running from front to rear, which may be four inches less in thickness than is called for by the clauses and provisions above set forth with regard to foundations, thickness, and height, provided they are not more than fifty feet in height; these walls shall be so located that the space between any two of the bearing walls of the building shall not be over twenty-five feet. **Iron or wooden girders, and bearing**

weight of same. In case iron or wooden girders, supported upon iron or wooden columns, are substituted in place of partition walls, the building may be fifty feet in width, but not more; and if there should be substituted iron or wooden girders, supported upon iron or wooden columns, in place of the partition walls, they shall be made of sufficient strength to bear safely the weight of two hundred and fifty pounds for every square foot of floor or floors that rest upon them, exclusive of the weight of material employed in their construction, and shall have a footing course and foundation wall not less than sixteen inches in thickness, with inverted arches under and between the columns, or two footing courses of large well-shaped stone, laid crosswise, edge to edge, and at least ten inches thick in each course, the lower footing course to be not less than two feet greater in area than the size of the column; and under every column, as above set forth, a cap of cut granite, at least twelve inches thick, and of a diameter twelve inches greater each way than that of the column, must be laid solid and level to receive the column. **Walls to be braced during construction.** Any building that may hereafter be erected in an isolated position, and more than one hundred feet in depth, and which shall not be provided with crosswalls, shall be securely braced, both inside and out, during the whole time of its erection, if it can be done; but in case the same cannot be so braced from the outside, then it shall be properly braced from the inside, and the braces shall be continued from the foundation upward to at least one-third the height of the building from the curb level.

"SEC. 8. **Cutting of wall.** No wall or any building now erected, or hereafter to be built or erected, shall be cut off altogether below, without permission so to do having been obtained from the Superintendent of Buildings. **Temporary supports.** Every temporary support placed under any structure, wall, girder, or beam, during the erection, finishing, alteration, or repairing of any building, or part thereof, shall be equal in strength to the permanent support required for such structure, wall, girder, or beam. **Braces.** And the walls of every building shall be strongly braced from the beams of each story until the building is topped out, and the roof tier of beams shall be strongly braced to the beams of the story below until all the floors in the said building are laid.

"SEC. 9. **Headers.** All stone walls less than twenty-four inches thick shall have at least one header, extending through the walls, in every three feet in height from the bottom of the wall, and in every four feet in length; and if over twenty-four inches in thickness, shall have one header for every six superficial feet on both sides of the wall, and running into the wall at least two feet; all headers shall be at least eighteen inches in width and eight inches in thickness, and shall consist of a good flat stone, dressed on all sides. **Heading courses.** In every brick wall every sixth course of brick shall be a heading course, except where walls are faced with brick, in which case every fifth course shall be bonded into the backing by cutting the course of the faced brick, and putting in diagonal headers behind the same, or by splitting face brick in half, and backing the same by a continuous row of headers. **Stone ashlar.** In all walls which are faced with thin ashlar, anchored to the backing, or in which the ashlar has not either alternate headers and stretchers in each course, or alternate heading and stretching courses, the backing of brick shall not be less than twelve inches thick, and all twelve-inch backing shall be laid up in cement mortar, and shall not be built to a greater height than prescribed for twelve-inch walls. All leading courses shall be good, hard, perfect brick. **Brick backing.** The backing in all walls, of whatever material it may be composed, shall be of such thickness as to make the walls, independent of the facing, conform as to thickness with the requirements of sections five and six of this act.

"SEC. 10. **Isolated piers, how constructed.** Every isolated pier less than ten superficial feet at the base, and all piers supporting a wall built of rubble stone or brick, or under any iron beam or arch girder, or arch on which a wall rests, or lintel supporting a wall, shall at intervals of not less than thirty inches in height, have built into it a bond stone not less than four inches thick, of a diameter each way equal to the diameter of the pier, except that in piers on the street front, above the curb the bond stone may be four inches less than the pier in diameter; and all piers shall be built of good, hard, well-burnt brick and laid in cement mortar, and all bricks used in piers shall be of the hardest quality, and be well wet when laid. **Walls and piers under girders and columns.** And the walls and piers under all compound, cast-iron, or wooden girders, iron or other columns, shall have a bond stone at least four inches in thickness, and if in a wall at least two feet in length, running through the wall, and if in a pier, the full size of the thickness thereof, every thirty inches in height from bottom, whether said pier is in the wall or not, and shall have a cap stone of cut granite, at least twelve inches in thickness, by the whole size of the pier, if in a pier, and if in a wall, it shall be at least two feet in length, by the thickness of the wall, and at least twelve inches in thickness. **Base stone.** In any case where any iron or other column rests on any wall or pier built entirely of stone or brick, the said column shall be set on a base stone of cut granite, not less than eight inches in thickness by the full size of the bearing of the pier, if on a pier, and if on a wall the full thickness of the wall. **Hollow walls.** In all buildings where the walls are built hollow, the same amount of stone or brick shall be used in their construction as if they were solid, as above set forth; and no hollow walls shall be built unless the two walls forming the same shall be connected by continuous vertical ties of the same materials as the walls, and not over twenty-four inches apart. **Height of walls, how computed.** The height of all walls shall be computed from the curb level. **Swelled or refuse brick, use of, prohibited.** No swelled or refuse brick shall be allowed in any wall or pier; and all brick used in the construction, alteration, or repair of any building, or part thereof, shall be good, hard, well-burnt brick. **Bricks to be wet.** And if used during the months from April to November, inclusive, shall be well wet at the time they are laid.

"SEC. 11. **Mortar, of what materials, and how used.** The mortar used in the construction, alteration, or repair of any building shall be composed of lime or cement, mixed with sand, in the proportion of three of sand to one of lime, and two of sand to one of cement, and no lime and sand mortar shall be used within twenty-four hours after being mixed;

and all walls or parts thereof, below the curb level, shall be laid in cement mortar, to be composed of cement and mortar, in the proportion of one of cement to two of mortar. No inferior lime or cement shall be used. **Sand.** And all sand shall be clean, sharp grit, free from loam; and all joints and all walls shall be well filled with mortar.

"SEC. 12. **Walls, how carried up and anchored.** In no case, shall the side, end, or party wall of any building be carried up more than two stories in advance of the front and rear walls. The front, rear, side, end, and party walls of any building hereafter to be erected shall be anchored to each other every six feet in their height by tie anchors, made of one and a quarter inch by three-eighths of an inch of wrought iron. The said anchor shall be built into the side or party walls not less than sixteen inches, and into the front and rear walls at least one half the thickness of the front and rear walls, so as to secure the front and rear walls to the side, end, or party walls; and all stone used for the facing of any building, except where built with alternate headers and stretchers, as hereinbefore set forth, shall be strongly anchored with iron anchors in each stone, and all such anchors shall be let into the stone at least one inch. The side, end, or party walls shall be anchored at each tier of beams, at intervals of not more than eight feet apart, with good, strong, wrought-iron anchors, one-half inch by one inch, well built into the side walls and well fastened to the side of the beams by two nails, made of wrought iron, at least one fourth of an inch in diameter; and where the beams are supported by girders, the ends of the beams resting on the girder shall be butted together end to end, and strapped by wrought-iron straps ot the same size, and at the same distance apart, and, in the same beam as the wall anchors, and shall be well fastened."

Preservation of Stone.—In the preservation of stone we now lay down, from the highest practical authorities, the condition upon which only a successful issue can be obtained:

First. The materials must be irremovable and imperishable.

Second. They must be easily absorbed by, and thoroughly incorporated with the stone.

Third. The materials must be free from color, but admit of imperishable coloration.

Mr. Frederick Ransome's process seems to best fill all the above conditions, meeting most thoroughly every possible requirement. The materials used are as follows: Dissolve flint or silicate of soda and chloride of calcium. Flint or silex is soluble by heat under pressure in a solution of caustic soda. In this form it is soluble silicate of soda. In this form it is to be thoroughly brushed into the stone. On top of this is brushed into the stone a solution of chlorine, which unites with the soda, forming an insoluble silicate of lime. The silicate of lime being white, there is an opportunity of using metallic tinting solutions.

Another process for the preservation of stone or brick is to dissolve resin (rosin) with turpentine, and when heated, to add linseed oil to form a paint.

Another mixture is made from unslacked lime, to which is added while slacking oil of tallow. When the slacking is complete, it is placed in a vessel with alum water and protosulphate of iron. After settling, it is drawn off and used.

Another process is the repeated application with a brush of a solution of beeswax in coal tar naphtha; when the color of the stone is to be preserved, white wax, dissolved in refined distilled camphene.

None of these, except the first, seem to offer any practical purpose, and only offer a temporary protection.

Here is a mixture, given by M. Kuhlman, that seems to have been used with success for thirty years. It is the silicate of potash. Before application the surface requires to be washed with a diluted solution of caustic potash with a hard brush. Three applications of the silicate are required during three days.

There is an English preparation extensively used for this very purpose of repelling moisture, and for the preservation of stone, brick, plaster and cement. It is a liquid or solution of silica. It is also used in kitchens, cellars and basements to form a hard surface on the walls, impenetrable to water. It is a kind of enamel, and is put up in barrels and by the gallon, and is red, white, blue, green and chocolate. It is applied with a brush, and is very inexpensive. It presents a surface like glazed tile, and is not affected by water or atmospheric changes. It is a silicate enameling paint. There are several agencies in the United States.

Incrustations on Brick Walls.—A greyish white substance, that appears on the surface of bricks, before being laid on walls, and afterwards; it proceeds from several causes: and since the discoloration is very unsightly, and if removed, may return, many builders and owners of buildings have tried various ways to get rid of this precipitate. It occurs generally on Philadelphia and New Jersey bricks for front facings. It is not seen often on the Baltimore or North River bricks. Limes that are burned of magnesian limestone produce a lime with a mixture of magnesia, and when made into mortar, and used in brickwork, absorb sufficient vapor from the atmosphere to form a sulphate of magnesium or epsom salts. It finds its way through every crevice and pore out to the surface. This sulphate of magnesia is found in a crude form known as silicate of magnesia, in native forms as asbestos, soapstone, talc and French chalk. When common salt is used in solution on brick, it leaves a white precipitate when dry. Portland cement contains but a small proportion of magnesia, and walls built with it show but little, if any, defacement. Some of the grades of Rosendale cement that contain magnesia and soda disfigure the surface of the walls when used in cement mortar. The best remedy is to remove the incrustation and wash the fronts, and when dry, paint the surface. If the surfaces are painted over the incrustations, it shows different shades of color when the paint is dry. This discoloration of brick walls is most noticeable in dry weather on parts of walls subject to dampness, and on entire walls after heavy rains. North and East walls are usually the heaviest coated. This white precipitate comes from both bricks and mortars.

To avoid this white defacement, builders should use limes free from magnesia; and cements free from magnesia and soda.

Avoid using bricks that are burned with coal, and also when the dry surface of the brick is whiter than the true color. When clays are to be used for making pressed brick for fronts or ornamental purposes, it is best to avoid all clays containing epsom salts or sulphate of magnesia.

The following may be a guide to finding the magnesia in clays:

Take some clay; dry the clay by heat; reduce it to a fine powder, andsaturate with sulphuric acid. Then dry and calcine the mass at a red heat, in order to convert any sulphate of iron (copperas) that may be present to a red oxide; it is then dissolved in water and sulphuret of lime is added, to separate any remaining portion of iron; then pour off the liquid and evaporate it, and the crystals that form, if any, are the sulphate of magnesia. This should be done by a chemist.

Sulphuret of Lime is made of—one part flower sulphur, two parts lime, ten parts water. This is the mixture used in testing the clay.

Of course, if the sulphate of magnesia is found, the clay is not fit for front or ornamental brick.

Yet it is possible to wash some clays and carry off the magnesia.

Another method of analyzing clay is as follows:

Grind the clay to a powder, and add diluted muriatic acid until it ceases to effervesce; heat it until the liquid evaporates, the residue being a thin paste; then add water and shake it; then filter the mixture and dry what is on the filtering paper by heating—this gives the insoluble matter; if magnesia is contained add clean water so long as any precipitate is formed; quickly gather the precipitate, and wash with pure water. The residue from washing is the magnesia.

Sand.—Whatever variety of sand is used in making mortars or cements, it should be granular, hard and gritty, sharp and angular, with a polished surface, and nearly uniform in size.

Sand, when perfectly fit to be used in mortar, will bear the test of being rubbed between the hands without soiling them.

Sand is not increased in volume by moisture, nor contracted by heat.

The finest sand screened should pass through a wire mesh one-thirty-second of an inch square; the medium size, one-sixteenth of an inch mesh.

The quality of mortar or cement depends chiefly upon the quality of the sand. The common practice of using unclean sands, or road drifts, argillaceous loams, and even alluvium or common soil cannot be too speedily abolished. Masons are apt to compound the mortar with the soil used from the foundations regardless of quality, suitability or the natural consequences of its employment.

Clean, sharp bank sand, free from loam and screened, is generally used in mortars for buildings.

As calcium or lime is used more extensively for mortars than anything else, it may be very desirable to give the various compounds.

Calcium Oxide,	Quick Lime,
Hydrated Calcium Oxide,	Slacked Lime,
Carbonate Lime,	Limestone,
Crystallized Lime,	Marble,
Fossil Lime,	Chalk,
Sulphate Lime,	Gypsum or Plaster of Paris,
Mineral Phosphate Lime,	Apatite.

There are more, but not required here.

CHAPTER VII.

On the preparation of Common Mortar.—The lime, when perfectly burnt in the kiln, should be packed in casks or air-tight vessels, and kept free from all moisture, and should be opened only as required.

Unslacked dry lime fresh from the kiln is termed *caustic* or *quick-lime*. After water is added to it, it is called slacked lime. The exact quantity of water for slacking is in proportion to the quality of lime; the fat or rich will absorb more than the poor or lean. No definite rule can be given for all localities for the use of water. The average is twice the weight of water to the lime, but this is only an approximation. It is important that the mortar should be used fresh.

The best or richest limes are made from pure carbonates of lime, which usually increase to twice their volume when slacked, but do not harden well in damp places. Poor limes do not expand much in volume; neither do poor limes harden well in damp places.

Limes that have been ground are usually of inferior quality, often mixed with refuse lumps and air-slacked lime.

Mortar, stuccoes or cements prepared from ill-burnt lime continue soft and dusty for a long time after being made whereas well-burnt and slacked limes soon become thoroughly indurated.

Rich limes hiss, bubble and throw off great heat during the process of slacking.

The purest limes require the largest proportion of sand and water, and harden in less time than the common limes.

Various substances are sometimes added to mortar to increase the tenacity, and they impart thereto the principles of hydraulic cement to a greater or less degree.

They chiefly consist of burnt clay, ashes, scoriæ, iron scales and filings, broken pottery, bricks, tiles, etc. They are useful in mixing with lime or mortar to increase their hardness, but they must be pure and reduced to a fine powder.

Some of the mason builders in New York and vicinity, who are large contractors, make building mortar for brick walls of the following proportions:

One barrel of lime,
Six barrels of sand—sharp bank sand,

which is calculated to lay one thousand bricks.

The average number of bricks laid on buildings around New York, Brooklyn, etc., for each man is one thousand per day. For mortars for this purpose many kinds of limes are used—Thomaston, of Maine; Briggs, North River; Snowflake lime, of Pleasantville, N. Y., etc., etc.

The proportion of one measure of quick-lime, either in lumps or ground (when lumps exceed three inches each way they require to be broken), and five measures of sand, is about the average used for common mortar by many masons. However, architects generally specify one part of lime to three of sand.

Mortar generally increases in volume one-eighth more than the bulk of loose sand.

In walls that are exposed to dampness, no lime should be used, as it will never harden properly. Cement should be used, or use burnt clay or fine brickdust, and mix it with the lime, as this forms a kind of hydraulic cement.

Shell lime is about the same as that from the purest lime-stone.

The average weight of common hardened mortar is from 105 to 115 pounds per cubic foot.

Common grout is merely common mortar made so thin as to flow like cream. It is used to fill the interstices left in the mortar joints of masonry or brickwork, and is perhaps best when a little cement is added.

Mortar should be applied wetter in hot than cold weather, especially in brickwork, otherwise the water is too much absorbed by the brick. To prevent this, dip each brick for an instant in water in some kind of vessel, especially if dusty, as it impairs the adhesion.

Where there is a heavy working strain brought on piers, or parts of walls, it would be best to use some proportion of cement, as the tenacity or cohesion in some mortars is not to be relied upon until four to six months after being used. This is only important where structures are heavily loaded or of considerable height.

The tenacity of good mortar is usually fifteen and one-half pounds per square inch, or one ton per square foot.

The crushing load may be taken at fifty tons per square foot.

Laying bricks or building walls when the mortar freezes always produces weak walls, and brings expense afterwards.

Common mortar of ashes is prepared by mixing two parts of fresh slacked lime with three parts of wood ashes together, and when cold to be well beaten, in which state it is usually kept for some time; and will resist alternate moisture and dryness. By some it is considered equal to some of the water cements.

A kind of cement plaster used around exterior foundation walls is made of one-quarter Portland cement, three-quarters lime, and two parts sand, with water sufficient to make a mortar. But Rosendale cement, small proportion of lime, if any, and one part sand to one of cement is the best; and even with this, where it is exposed to dampness, it is best to coat the cement with a coat of asphaltum.

To Color Mortars.—This may be done by the use of various colored sands. There are yellow, silver and grey sand to be had in many localities. Colored mica, put on the surface of stucco work with a thin mixture of limewater and lime, first wetting the surface, leaves a durable and sparkling finish. Pulverized bricks, yellow or red, may be used. Pulverised dust from colored marble, also basalt dust, are all durable. Ochres seldom stand exposure to the weather.

Where black has been used for pointing the joints of brickwork, the mortar requires so much black to make the color that the mortar becomes poor, and washes off.

Spanish brown is a species of earth of a reddish brown color, which depends upon the sesque-oxide of iron.

A dry powder, known as Spanish brown, added to cement or mortar is considered a permanent color.

Gravel Sidewalks are usually laid by mixing the gravel with the sand and lime; *i. e.*,

Ten bushels of gravel.
One to two bushels of sand.
Half bushel of lime.

Of course it is required to dig trenches, and lay down common concrete, to bed the walks on, or broken stone.

To Color Bricks Black.—Heat asphaltum to a fluid state, and moderately heat true surface bricks and dip them.

Another method is to make a hot mixture of linseed oil and asphalt; heat the bricks and dip them. Tar and asphalt are also used for the same purpose. It is important that the bricks be sufficiently hot and held in the mixture to absorb the color, to the depth of one-sixteenth of an inch.

Also, **for Staining Bricks Red or Black.**—A process similar to staining bricks red will answer for staining them black, by substituting lampblack for the red employed. For the red, melt one ounce of glue in one gallon of water. Add a piece of alum the size of an egg, then one-half pound Venetian red, and one pound Spanish brown. Try the color on the bricks before using, and change light or dark with the red or brown. For staining black use the same, and instead of the alum use bi-chromate of potash. Use when made, and in dry weather.

Venetian Cement—Used for covering floors, terraces and roofs of houses, is composed of plaster of paris, sulphur, rosin, pitch and spirits of turpentine or wax, and applied when hot.

Coal Ash Mortar.—Lime, two and a half measures; sand, two and a half; coal ashes, two and a half; and puzzolana, one and a half.

Dutch Terras Mortar.—(Terras is a basaltic mineral found in the low counties of Holland.) This was formed of equal parts of lime and trass by measure.

Puzzolana Mortar—For lining cisterns, consisted of slacked lime, sixteen parts or measures; puzzolana, eight; sand, five and a quarter; beaten glass, four; and smith's cinders, four. This was, with the other three, used at Gibraltar in 1790.

Very fat lime is incapable of hardening in water.

Lime, a little hydraulic....................	Slakes like lime when properly calcined, and hardens under water.
" quite "	
" " " 30 per cent. clay...	

Lime.	*Clay.*		
60 per cent.	40 per cent.	Plastic or hydraulic cement	Does not slake under any circumstances, and hardens under water with rapidity.
50 "	50 "	" " "	
40 "	60 "	" " "	
30 "	70 "	Calcareous brick puzzolana.	Does not slake nor harden under water, unless mixed with fat or hydraulic lime.
20 "	80 "	" " "	
10 "	90 "	" " "	

TABLE.

One Bushel	Mortar........................	130 pounds.
One "	Sand....................	110 to 120 "
One "	Lime..........................	80 "
One "	Hair..........................	8 "

Cattle hair is collected from tanneries. It is best of medium length, fresh and clean. Vegetable fibre of hair has been used some, but not extensively.

Plastering or Stucco.—When buildings are plastered on the exterior, or parts exposed to the weather, it is usually called stucco-work (the same word stucco is in use for inside work). But this kind of finishing rough walls is not much in use in this country.

There are two kinds of stucco; those made of lime, and those of cement. Cement stucco is disagreeable in color, and only used where protection to the walls or a very hard surface is wanted. The cement color may be covered with paint, and when used it is often painted. In working the first coat it may be well to work it with cement plaster, and for the second coat use equal parts of quicklime and cement with silver or light grey color sand. Colors mixed with the stucco, such as umbers or ochres, get dingy and very unsightly in time. Mineral color that is not liable to atmospheric change is the best.

To make a light brown shade, use silver or as white sand as possible, and in this mix pulverized brown stone or brown sandstone. The pulverized stone dust from colored marble may be used, also basalt dust, but ochres seldom stand the weather.

Pulverized bricks, yellow or red, may be used where the color is known to be permanent. The same process as mentioned above is the best for exterior pointing, as most coloring substances wash off.

An external stucco, when made with hydraulic lime of Tiel, is composed thus: Lime of Tiel, one part; two of chalk, and two of sand.

Exterior walls have to be prepared for plastering by wetting them, and leaving the joints open and rough, and during the work to have the green material protected from the weather, particularly drying winds or heat of the sun. This is done by using muslin or canvass on the scaffolding.

Exterior plastering or stucco is usually done in two coatwork. Both coats done about the same time—that is, the first coat is done sufficiently long for it to have set in the joints, and to sustain the second coat.

The plasterer examines his work to find any places where it has not adhered—say three or four days after the work is first done.

Lime and cement, equal parts (that is, thoroughly mix the lime before compounding with the cement, sand and water), mixed with sand and water, makes a good stucco.

An artificial stone stucco, which seems very good, is made of one part lime or cement and four parts sand, to which after slacking add four ounces potash or soda, dissolved in one gallon boiling water, and add one pound shellac. When this is dissolved mix with the plaster, and use at once.

There are quite a number of cements that do not stand well for stucco-work.

Inside Plastering—Is done in a variety of ways, from one to three coats of mortar plastering on walls, ceilings, etc.

When one-coat work is required, the plasterers have to be careful in laying or nailing the laths regular. One-coat work is known as the scratch coat, and generally finished with light hand-floating to give an even finish, to receive a white or color wash finish if desired. If it is the intention to kalsomine on one-coat work, a very good finish may be made by using some *hard-finish* on the hawk (a flat board to hold plaster on, held in the hand), and hand-float the surface with water in the brush. Back buildings and the second stories and attics of farm-houses are often finished this way. It is very important to put on the first coat, to press the mortar firmly between the laths, to fill up the spaces between, and bulge over the edge of the laths. When the first coat is done to receive the second or browning coat, the surface, before being perfectly dry, is scratched or pricked up on the surface with a hand-rake made of laths; the lines are generally crossed like lattice-work, but rough.

The proportion for the scratch coat is as follows: One part quicklime, four parts sand, and one-quarter to one-third measure of cattle or goat's hair; and it is usually put on from three-eighths to one-half inch in thickness.

For Two-coat Work and Finish.—The scratch coat is generally done as in one-coat work, and worked on the surface roughly, but level surfaces with hand-floating. It is required to keep the work plumb and true, and scratched to receive the second coat, which is known by the name of *browning.* Where, as in this case, the plastering is finished with two coats, the second coat is usually one-quarter or three-eighths inch thick, and will make a very handsome finish if done with clear grey or silver sand; mixed with one part *guage stuff* or plaster of paris putty, one part *fine stuff* or lump lime slacked into a paste, and three parts sand, with sufficient clean hair to hold in position the coat when set. This coat is thoroughly floated and troweled.

Another way is to use the same mortar, known as *coarse stuff*, for the second coat, but with less hair, and before it is dry to float it thoroughly with hand-float, brush, trowel and water, with some *guage stuff* and a little sand, forming a skim finish. This is done in several ways, but with slight variation, the same material being used.

Three-coat Work and Finish.—Prepare wood furring by covering it with wood or metal laths. Wood laths should break joint every eighteen to twenty inches, and laid about three-eighths to one-half inch apart. On this work the first or *scratch coat* is to be placed on the wall, and after it is thoroughly dry, followed with the second or *browning coat*; and the third is *guage stuff* for hard-finish. This is worked on the second coat with a trowel for one hand, and sometimes for two hands; and by using a brush in water; skilled mechanics often make very fine surfaces in this manner. This coat is usually one-eighth inch thick, and is composed of *fine stuff lime*, slacked to a paste, three parts; plaster of paris, or *guage stuff*, one part. No more is made than can be worked up in say half an hour.

Guage stuff is used chiefly for mouldings and cornices—the moulds being made of zinc or sheet iron, and secured to a wooden template, with handles to run the template with mouldings. For this purpose it is common to mix gradually one-third plaster of paris with two-thirds *fine stuff*. When the work can be done rapidly, equal parts may be used.

Guage stuff is used for securing ornaments to the walls or ceilings and plaster decorations. Plasterers cast sections of ornamental cornices in lengths of about three feet, and bring them fresh to the structure, and set these pieces in position. By this means rooms are decorated in New York and vicinity at about the same price as plain, heavy moulded cornice work can be done. The moulds that are used for this purpose are made of wax, rosin and oil, and are usually kept for use by ornamental plasterers.

Stucco finish is usually made of *fine stuff* with white sand—four parts sand, and one part fine stuff. There are other rules for stucco finish.

Brick walls require less cattle hair in the plaster than on laths, and usually stone and brick walls have but one strong wall coat, and on this it is finished with lime and plaster of paris, as in the last coat of three-coat work. The walls should be rough, clean and dampened.

One hundred yards of plastering will require 1,400 laths, four and a half bushels of lime, eighteen bushels of sand, nine pounds of hair, and five pounds of nails for two-coat work.

One hundred yards of plastering for three-coat work requires seven bushels of lime, one load of sand, nine pounds of hair, five pounds of nails, and 1,400 laths.

Several plasterers in New York and vicinity give the following data: 1,000 laths will cover fifty square yards. One barrel of lime, one cart-load of sand, and three bushels of goat hair will scratch coat and brown coat a surface of twenty-five square yards.

Oyster-shell lime is only used for scratch coats, owing to the salt in the lime. Wood-burned lime is always the best. A great quantity of Pennsylvania lime is burned with coal, and has to be sifted, leaving often too large a proportion of *core*, which has to be thrown away. Nearly all plasterers use the lime that will work the easiest with least labor, and use materials that pay the best with labor. Thomaston or Rockland lime is used by plasterers generally in vicinity of New York. Glenn's Falls lime is very pure, and is used only in the ornamental arts.

PLASTERING.	1 INCH.	¾ INCH.	½ INCH.
One bushel Cement, or 1.28 cubic ft., will cover.	1⅛ sup. yd.	1½ sq. yd..	2½ sq. yds.
One " " and one of sand..........	2¼ "	3 " ..	4½ "
One " " " two "	3¼ "	4½ " ..	6¾ "

One cubic yard of lime, two cubic yards of sand and three bushels of hair will cover seventy-five superficial feet of rough or scratch coat on wall, or seventy yards on lath.

One bundle of laths and 500 nails will cover about four and a half yards.

1,000 laths will cover 666 square feet.

Hydraulic Limes and Cements.—If limes harden under water in from fifteen to twenty days after immersion, they are slightly hydraulic; if from six to eight days, simply hydraulic, and from one to four days, eminently hydraulic. Hydraulic limes, if not properly slacked, will sometimes burst. It should all be hydrated before placing, which will require more time than ordinary lime. The different kinds act differently. There is but little heat developed in these limes while slacking.

The hydraulic lime of Tiel, manufactured in France, and imported to this country in barrels of from 450 to 600 pounds, is extensively used, and considered a very strong cement. It will set firmly in eighteen to twenty-four hours under water, and increases in tensile strength from 40 to 160 pounds per square inch, and the crushing weight from 200 to 600 pounds per square inch. It weighs from 40 to 45 pounds per cubic foot. The slacking of 100 pounds of Tiel lime requires 28 pounds of water.

For Salt-water Mortars, Concrete, under water.—One part of Tiel lime to two parts of sand.

For Mortars Exposed to Air.—One part lime, three parts sand.

To Form Betons or Concrete from the Mortars before mentioned.—*Salt Water Concretes*—Two measures of mortar, thoroughly mixed with three of broken stone.

Fresh Water Concretes.—One measure of mortar to two of broken stone.

Artificial Blocks.—One measure of mortar to two of pebbles.

Portland Cement is made of argillaceous limestones selected for the purpose, or argillaceous chalk or calcerous clays, or mixtures of artificial carbonate of lime or clay, and artificial mixtures of caustic limes and clay.

It is burned in kilns with a heat of sufficient duration and intensity to produce the beginning of vitrifaction. After this the product is ground to powder. There should be from seventy to eighty per cent. carbonate of lime, and twenty to twenty-five per cent. of clay, and not less than ninety to ninety-five per cent. of the lime and clay required for a first quality cement. Hard carbonates of lime are expensive to reduce to powder, yet hard limestones may be used. Suitable clay is of more rare occurrence than suitable limestone, for the reason the former must contain alumina and silica, not only in certain proportions, but in a certain state of pulverization.

For foundation walls on damp and yielding soils, also for sub-marine masonry, Portland cement concrete is superior to brickwork in strength, durability and economy. It is also well suited for sewers, piers, abutments, pavements, etc. A barrel weighs about 400 pounds, and has a tensile strength of 250 pounds per square inch, and safely sustains, after seven days set, 470 pounds per square inch.

Concrete or Beton is a mixture of lime, sand and gravel or broken stone, or hard-burned broken brick. When cement is used instead of lime, it is known as a cement concrete.

The object to be attained in making hydraulic concrete is to give such a sufficiency of mortar as will produce the aggregation of the whole mass of rough rubble materials.

When Portland cement is used, one part of cement may be used to three parts of sand, and this may be mixed with six parts of gravel, stone, spalls or broken bricks.

For Tiel lime, three parts, five parts sand, and add two parts broken stone. This is as it was used at the mole in Marseilles.

The French Beton Agglomere.—Cement in blocks con, sist of 180 parts of sand, 44 parts of lime slacked, 33 parts of Portland cement and 20 parts of water. This is most thoroughly incorporated.

Vicat Cement.—This artificial cement sets strongly in from eight to fifteen hours, and is able to stand great cold. Vicat mortar, of one part of cement to three parts of sand when fourteen days old, sustained safely a pressure of 300 pounds per square inch.

Lafarge Cement—Weighs sixty-six pounds per cubic foot. Begins setting after three to three and a half hours; completes its setting in twelve to eighteen hours.

Made into Mortar.—One part cement to two parts sand. After eight days setting, its tensile strength was found to be 142 pounds per square inch.

Made into Mortar—One part cement, three parts sand. After three days setting, did not crush until loaded with 81 pounds per square inch. The same mixture,

After	13	days	540	pounds	square	inch,	crushing	load.
"	33	"	942	"	"	"	"	"
"	48	"	1049	"	"	"	"	"

In practice it would be safe to use a working load to the above of one-quarter of the crushing load.

The resistance to rupture after twenty days exposed to the air, is about 54 pounds per square inch; with equal proportions of sand and cement it falls to 27 pounds.

American and Foreign Cements.—

American Rosendale	from	60 to 70	pounds	cubic	foot.
English Portland	"	95 to 102	"	"	"
And in barrels	"	400 to 430	"	"	"
French Portland	"	95 to 105	"	"	"
Lafarge	"	66 to 70	"	"	"
Tiel Lime	"	52 to 58	"	"	"

The following cements were made into small blocks, four inches square by one inch thick, and they set as follows:

Statine, French Cement	15	minutes
Pomeranium, German	13	"
K and S Portland, imported	11	"
White's " "	7½	"
Rosendale, U. S.	30 to 45	"

They were tested with a piece of wood, the size of a common clothes-line pin, and were tapped; when no impression was made, they were said to have set.

Keene's Cement.—An imported cement, is used extensively for interior decorations, artificial marble cornices and center pieces. The superfine is of a delicate white, takes a high polish, and makes beautiful scagiola work. There is a medium used for the same purpose, and used in artificial marbles. The coarse is used for stucco, and has great durability; also for floors to halls, areas, passages, vestibules, churches, etc. It is less expensive than Portland cement. One cask contains four bushels, which, mixed in the proportion of one part cement, and two parts sand, will cover about fifteen superficial yards one-half inch thick.

For Polished Work of Walls.—Use the floating coat of equal parts coarse Keene's cement and sand; the setting coat to be one-quarter inch thick of the superfine.

For Stucco on Brickwork.—For floating coat, one part cement, and two parts sand. The setting coat should be three-sixteenths inch thick.

Where it is required to lay a coat of cement over a floor surface, one barrel of Portland cement, weighing about 400 pounds, if used neat, will cover five square yards of surface one inch thick; and when mixing, if there is added two parts of sand, it will cover fifteen square yards of surface one inch thick.

Rosendale Cement Concrete. — One barrel Rosendale cement, 300 pounds weight, 75 pounds per bushel; three barrels of sharp, gritty and damp sand; five barrels of broken stone; will sustain a load of 40 pounds square inch when set.

Portland Cement Concrete. — One barrel of Portland cement, 400 pounds, say five cubic feet; one barrel of Thomaston lime, eight barrels of sand, twelve barrels of broken stone; will sustain a load of 50 pounds square inch when set.

Rosendale cement weighs about 75 pounds per bushel; Portland cement will average 116 pounds per bushel, when 90 per cent. fine. Dark cement appears to be the strongest. Fine quality cements are now manufactured in many of the United States. The best are from Rosendale cements of

New York and New Jersey; Cumberland, Maryland; Round Top, Hancock, in Maryland; Sandusky, Ohio, and Shepherdstown, Virginia.

Nearly all hydraulic limes and cements, after being packed in barrels, will lose their energy by exposure or age.

The imported Boulogne Portland cement, after getting a permanent set, will sustain a load of 1000 pounds per square inch. Its tensile strength is 340 pounds per square inch. It is most desirable for strong masonry, wharves, piers, foundations, sewers, etc., and concrete sidewalks. It takes several hours to set.

For Mortar of Great Strength—One part Boulogne cement, five parts coarse sand.

Silentic Lime or Cement—Is prepared by mixing and grinding together unslacked high-degree hydraulic lime and calcined plaster of paris, in the proportion of ninety per cent. lime and ten per cent. plaster of paris. When made into mortar with sand it sets quickly and firmly, and can be used for concrete of mason's work; is durable and very firm and strong. The only silentic cement process used in this country is the Howe's Cave cement, New York.

For certain purposes the natural light cements, and those manufactured in the United States, possess sufficient strength for the purposes to which they are applied: For massive concrete foundations and walls, for the backing of thick walls faced with ashlar, and to giving hydraulic energy to mortar for stone and brick masonry, and there are several high grades of Portland, New York and Pennsylvania equal to those imported from Europe.

Cement Mortar for Brick-laying.—One part cement, two parts sand. *For Stone-work, ordinary*—One part cement, three parts sand.

Mortar of Cement.—One barrel of cement, say 300 pounds, two barrels of sand, one-half barrel of water, will make say eight cubic feet of mortar, and will lay 500 bricks, or one cubic yard of rubble stone-work. Three or four more parts of sand may be added, according to quality of work.

Cement Mortar for Stone Masonry—*i. e., Cut or Squared Mason Work.*—One cask of cement, say 300 pounds, ninety per cent. fine; one-half cask lime, *Thomaston;* fifteen cubic feet of sand.

The mixing of lime with cement makes the cement set slower, and is also cheaper.

Cement Mortar for Brick Masonry.—One cask of cement, one-half cask of lime, four cubic feet paste, and ten cubic feet of sand.

Where cements are used on masonry of railroad work, the proportion of mortar is one-third of cement to two-thirds of sand, and sometimes lime is added.

Ordinary Concrete.—One part cement, one part lime, two parts sand, and four parts granite spalls or shingle.

Brickdust Cement Concrete.—One measure or part of new lime, one and one-quarter measures or parts of brick or tile dust, one and one-quarter measures or parts of sand, five measures or parts of broken stone, and water.

Lime and Cement Concrete.—One-half bushel cement, three-eighths bushel lime, two bushels sand, four bushels broken stone, and three-eighths bushel water.

Lime should always be slacked a day or two before mixing the concrete.

TABULAR STATEMENT OF TESTS MADE ON HYDRAULIC AND OTHER CEMENTS AT THE CENTENNIAL EXHIBITION, PHILADELPHIA.

All these cements were tested by mixing them dry, in every case with equal quantity of clean sand, tempering it to the consistency of stiff mason's mortar. Then they were moulded into small bricks, equal to two and one-quarter square inches of surface, allowed one day to set in the air, and placed in water for six days. After a number of trials on each, the result was divided by two and one-quarter to get the load on each square inch:

CEMENTS.	*Crushing strength per square inch.*	*Tensile strength per square inch.*
Stettin, German, Portland Cement	1,436	206
Hollick's Portland, London, Eng	1,300	212
Wouldhan's " " "	1,150	200
Saylor's Portland, Allentown, Penn., U. S.	1,078	184
Portland Wampum, New Castle, Penn., U. S.	968	168
Pavin de Laforge, Tiel, France	931	158
A. H. Lavers', London, Eng., Portland	926	192
Francis, Portland	907	163
McKay, Ottawa, Canada	882	141
Delfzyl, Netherlands	826	132
Longuety & Co., France	764	108
Riga Cement Co., Riga, Russia	693	134
Scanian, Sweden	606	112
Estland, Russia	580	154
ROMAN AND OTHER CEMENTS.		
Coplay Hydraulic, Pennsylvania, U. S.	292	38
Manlius, New York, U. S.	276	47
Seigfried Bridge, Pennsylvania, U. S.	276	43
Gauvream, Quebec, Canada	234	47
Riga, Russia	230	44
Cumberland Hydraulic Cement Co., Maryland, U. S.	200	42
Societe Anonyme, France	184	29
Anchor Cement, Allentown, Penn., U. S.	201	42
Howe's Cave Association, New York, U. S.	184	42
Societa Anonima, Emelia, Italy	180	27
Gowdy, Ontario, Canada	126	24
Lavers, London, Eng.	122	25

There would naturally occur many reasons for the above tests being variable, owing to the selection of cement for the test, and exposure to the heat of the sun, etc. Most of the above data was obtained from nine to twelve tests on each kind of cement. Thirty-three per cent. of the test would give a fair working load for foreign cements, and forty per cent. for the United States, as every year great improvement is being made in the manufactures of all grades of cement in this country; and the tests are open to such criticism, owing to competition and use here, that they may be relied upon.

When Portland Cement is made into blocks without sand and filled in moulds, and turned out after twenty-four hours, they may then be immersed in water, and at the expiration of eight days they will give a tensile strain, slowly applied, of 250 lbs. square inch.

Street Pavements.—In England about 1842 many wooden pavements were laid in every style. The roadways were prepared with sand surfaces, boards laid flat on the surface, and lumber or timber, cut at all angles, with cross-pieces set in. Then again tarred boards were set on edge for another kind, and round chestnut and varieties of woods set on edge, turned and squared, for another kind. Planked roads of every variety were made in certain localities. When most of these had been worn out, and renewed, ten years later most of them disappeared. But now the wood is prepared with salts of lime, iron, copper, etc., and coated with asphaltum, and in some localities in London they seem to have come into use again.

Wooden pavements, that were laid of the various patents in New York City have nearly all disappeared. The best appeared to be those coated with asphalt, and set on edge on a wooden board surface, leaving spaces that were filled with gravel. The heavy traffic and wear from the large trucks in New York soon destroy the surface, and keep the streets in almost impassable condition in winter. They are not renewed in New York. In Elizabeth, N. J., and many parts of New Jersey, where wooden pavements have been laid, they have lasted only from five to seven years. When they are partially worn out the accumulation of water under them, with exposure to air, and sun, soon rots the whole surface.

A properly laid Macadamized pavement is decidedly superior, when properly done, to any wooden pavement. All round-wood pavements become uneven after the expiration of one or two years, and it is as bad as an uneven cobble-stone roadway.

Some wooden pavements laid in Boston, Mass., seem to have met with better success than in the States of New York and New Jersey. There the wooden blocks were set on edge on a sand bottom six inches deep. Wooden pavements laid of pine or spruce cost on an average $2.25 per square yard.

The next kind of pavement that has been used extensively in suburban cities, and some in New York and Boston, is known as asphaltum or bituminous concrete pavements and sidewalks; but the severity of the climate here is such that the frost in winter breaks and injures it to such an extent it is not considered a reliable pavement this far north, although the appearance and surface for walking is so desirable. It costs from $2.00 to $3.00 per square yard.

A four feet in width flag-stone sidewalk is the best for village walks. They average from three to four inches thick. Of course if the width is greater it adds to the expense.

A five feet stone flagging will average 65 cents per running foot of that width.

Sidewalks with stone curbing, and laid with hard bricks in the various styles, may be laid successfully, where there is a tendency for the frost to raise the surface, by providing a sand bottom of twelve inches in depth of sand; and slush the surface with a grouting of cement and lime, then paste. Roll the surface before it sets, and lay the brick in a grouting of cement. This can be done very fast by ordinary labor, and it has made most excellent work. Have a firm bottom.

Macadamized Roadways—Are usually built by laying down eighteen inches of large stone, blended with fine sand or gravel six inches in depth, with a somewhat smaller stone. Then on this six inches of ordinary broken stone and gravel, each layer when placed being subjected to a heavy roller and water freely used. On country roads water cannot be used, and as a matter of course it is dispensed with.

Artificial Stone Pavements or Sidewalks. — There are several variety of these in the United States, but they do not seem to stand well when laid as far north as New York City or Boston. They are mostly made of Portland cement, and large sharp sand, in blocks from three to six inches in thickness, and from two to six feet square. The proper method is to lay them on a concrete foundation. Porous material is the best for making concrete, as it allows the cement to enter the pores; all stone and gravel should be wet before adding the cement. One of the best pavements of this kind is the Schillinger artificial stone pavement, and costs an average of 20 cents per square foot. He also makes an asphaltum paving block, laid on concrete. The blocks are about four by twelve inches, and are not affected by the action of frost as ordinary asphaltum pavements are.

The streets of New York City, Brooklyn, Jersey City and Newark use the following street pavements:

Belgian Pavement.—This consists of stones, 5x6x6 inches, laid on a bed of sand six inches deep. These vary in size to 4x8x10, set on edge. Cost about $3.50 per square yard. They are using on Vesey street a fine paving stone, a kind of moderately soft granite, from the vicinity of Richmond, Virginia. Large quantities of paving stone come from New Jersey, known as Trap and Basalt stones.

Guidet Pavement.—This consists of granite blocks, averaging 12x5x8 inches, laid on six inches of concrete and six inches of sand. It is laid on Broadway, New York, and costs about $5 per square yard.

Sidewalks.—The sidewalks in New York City and Brooklyn are laid with blue-stone flagging of various thicknesses, and is brought from quarries convenient for transportation down the North River. Granite flags are sometimes used, average ten inches in thickness, and sometimes measure 8 feet by 15 feet. These require no curbing. The blue stone costs about $3 per square yard.

In Baltimore, Boston and Philadelphia brick is chiefly used, cost varying to suit localities, say $1.20 per square yard.

Concrete sidewalks are made of a mixture of tar and gravel, and a concrete of asphaltum cement and gravel, is also used, but do not seem satisfactory for much travel, owing to the action of frost and ice in winter.

Street pavements in Boston are usually of granite blocks, 4x7x8 inches, laid in from 8 to 12 inches of gravel or sand, and cost about $3.25 per square yard.

In Buffalo and Rochester Medina stone is used; the blocks vary from 2 to 4x8x8 inches. They are laid on 16 inches of sand, gravel or broken stone. It costs about $3 per square yard, and is very satisfactory.

Method of Calculating Loads on Floors, etc.—Illustrations 38 and 39 show a plan and elevation, representing piers and walls of a structure that adjoins another building, or it may be independent. Also shows diagrams of loads supported on floors. The base stones are ordinary in size, and generally such sized base stones are used where the load is not important. In buildings that carry an actual load on each floor of say 160 pounds per square foot of floor surface it is best, where the bottom is firm, to lay two bases of footing stones, the first stone to average five feet square, and the second four feet six inches square, with a brick pier built on them, say three feet four inches square, bonded with four-inch flat stone—may be blue stone—every two feet, and capped with a granite block, ten to twelve inches thick.

It is important that all piers to support inside columns (whether of iron or wood) should have brick and mason-work done in the best manner, with equal joints, and allowed to dry in toward the center of pier before placing the weight of several stories on it, when the load comes direct on the piers. In reference to the load of goods, materials, etc., in stores, after making a calculation of ten or twelve stores, the load in the stores on the first, second and third stories did not exceed 170 pounds per square foot on surface, and above that the load would average from 90 to 100 pounds per square foot of surface. Allow for load on roof for snow, etc., 90 pounds per square foot. In warehouses, such

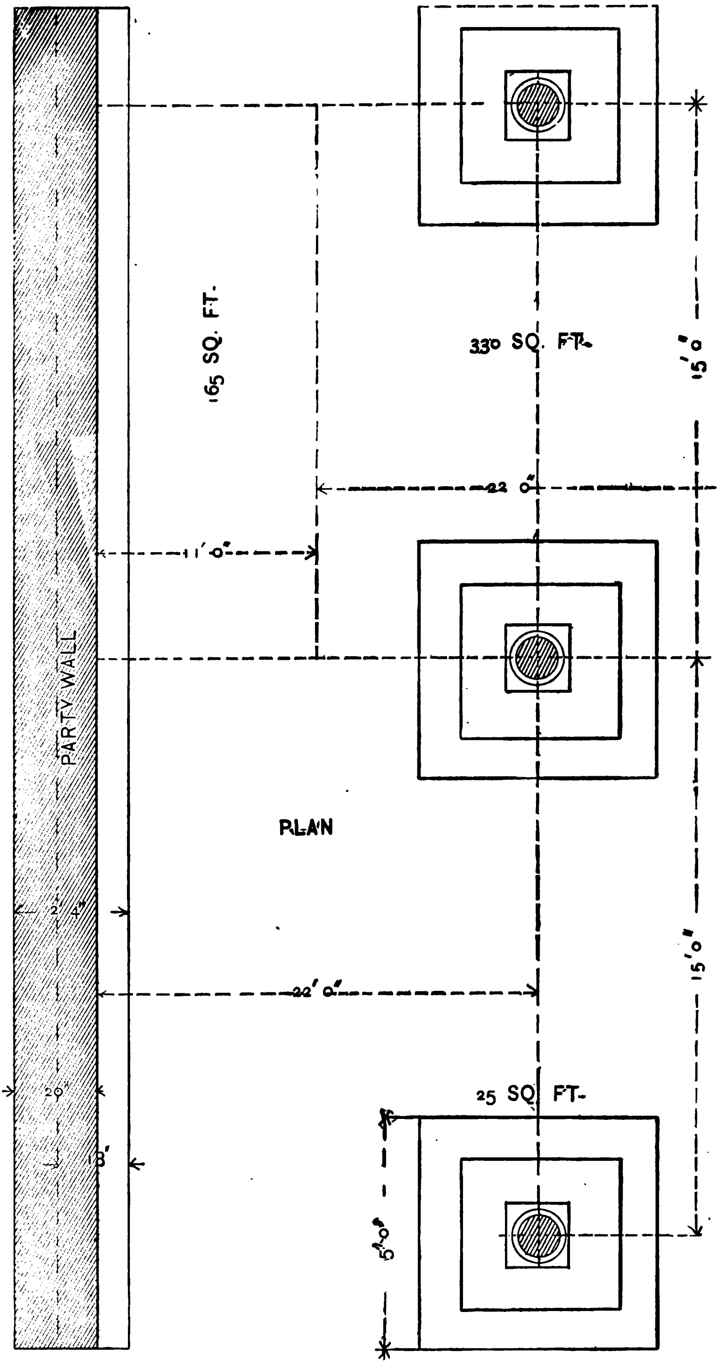


Illustration 39.

as for hardware, cottons, groceries, etc., the load averaged 260 pounds per square foot of surface. As a guide and a safe rule, the Building Department has, for this purpose, tables of the load on floors, which you will find in this book. See Contents.

The average size piers used for store construction run as follows:-For four and five story buildings, where the business done is ordinary or general, piers average from three to three feet eight inches square, with five feet square to five feet eight inches square base stones. Some double stores (fifty-feet fronts), lately built in New York, have a line of piers in the centre, supporting iron columns. These piers are 2 ft. x 2 ft. 8 in. x 10 ft. high, with the first footing 5 ft. 6 in. x 5 ft. x 16 in. thick; the second footing stone, 4 ft. x 4 ft. 6 in. square, by 12 in. thick; these buildings are seven stories and 98 feet high.

The footings and base stones to Stewart's store, Tenth street, New York, did not average above six feet six inches square. This structure is about 130 feet high above the footings. The footings and base stones to the Western Union Telegraph Building, New York, average eight feet square and twelve inches thick, and some parts have inverted arches. This building is 144 feet high from footing stone to top of main cornice, and above this is an iron roof three stories in height. The footings for the Morse Building, Nassau street, New York, are eight feet square, and the piers are five feet square. The walls average three feet four inches thick to second floor. This building is 160 feet high. The Coal and Iron Exchange, Courtlandt street, is constructed on piers and inverted arches on the fronts facing the streets.

On illustrations 38 and 39, showing piers and walls, the method of calculating the load on floors by the square foot is shown by the diagram. The space from the wall to the center of the pier is figured 22 feet, and from one pier to the other, 15 feet. To ascertain the load sustained on the columns, and on each pier, multiply 15 by 22=330 square feet. This multiplied by a load of 250 pounds per square foot will give a load on each floor, supported by column on pier, of 330 square feet, multiplied by 250 pounds square foot, equals

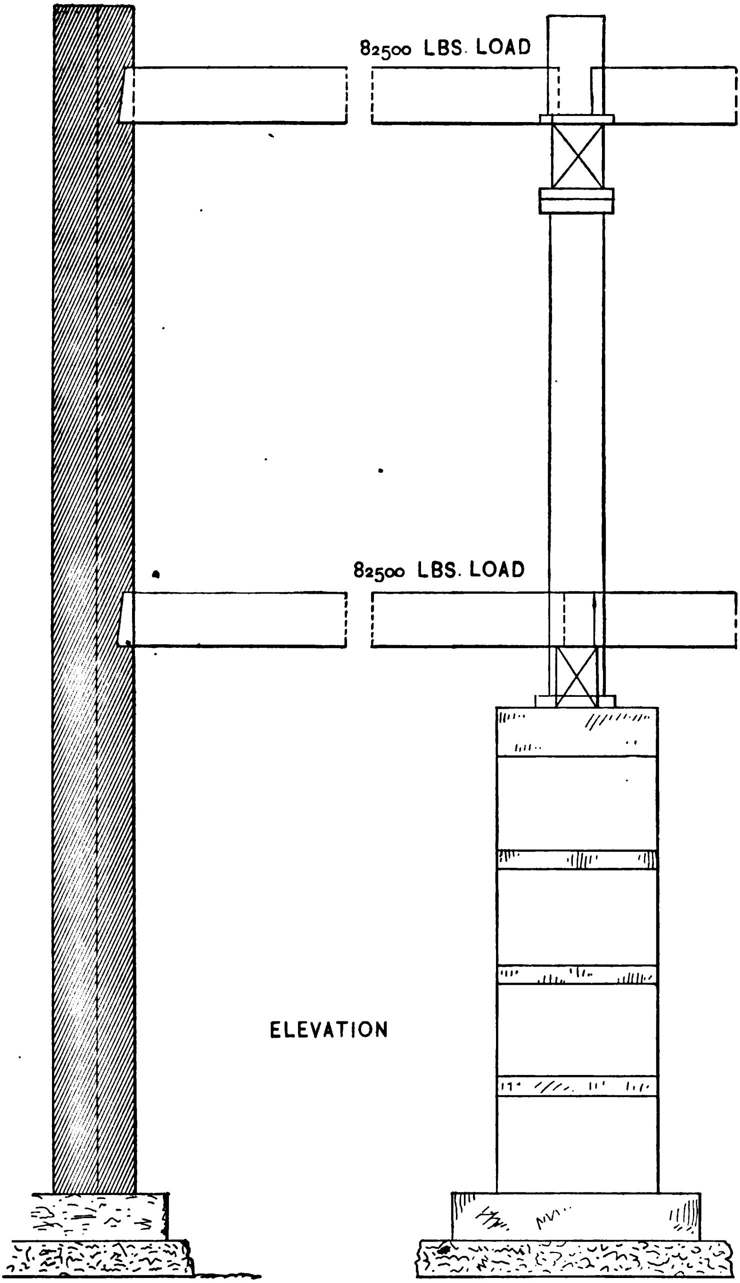


ILLUSTRATION 40.

82,500 pounds. This load is independent of the weight of materials required in the construction, for which see tables, in index. Of course every floor has to be calculated, which sometimes shows an immense load resting on the piers, as much as 250 tons. Where wooden girders are used, the piers are placed from ten to twelve feet from centers. When iron girders are used, the piers are usually from twelve to sixteen, eighteen or twenty feet on centers. The load on base stone should not exceed five and one-half tons per square foot of bearing surface on base stones of five feet square, which gives twenty-five square feet. All base stones in and about New York City for good construction have from six to eight inches of concrete for a bed.

It is not unusual with a good foundation to load base stone to piers with from seven to eight tons per square foot of surface.

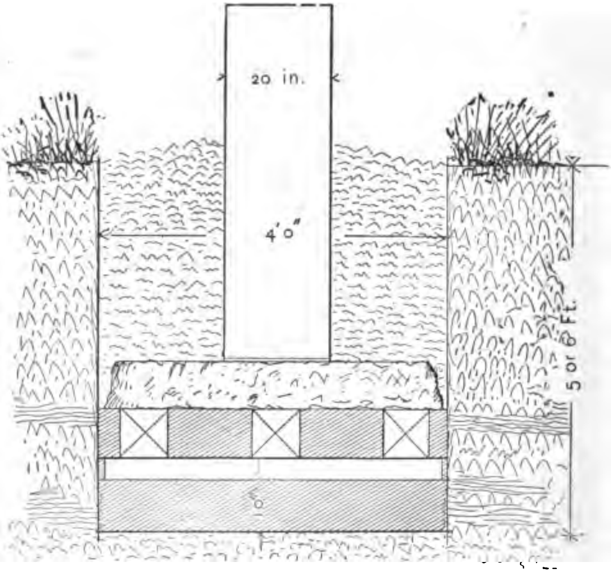


ILLUSTRATION 41.

Illustration 41 represents the foundations to a factory building, erected near the edge of the water line in the marshes of Long Island. The soil is a stiff black muck. Trenches were cut through this four feet wide, and averaged six feet deep to a partial quicksand bed. The building is 50 by 80 feet; two stories, 16 feet each; with four feet of brick-work, above ground, to level of first floor. The walls above are sixteen inches thick. After the trenches were dug, a bedding of ten inches in thickness of concrete was laid. On top of this two inches spruce plank are laid crosswise, followed with 8x8-inch timber, laid parallel with the trenches, and the spaces filled in with concrete. On this are laid the base stones, on top of which is built a twenty-inch brick-wall. The trenches on each side of wall were filled up with sand.

This factory has an engine, boiler, machinery and shafting, with an hundred operatives. No settlement has occurred.

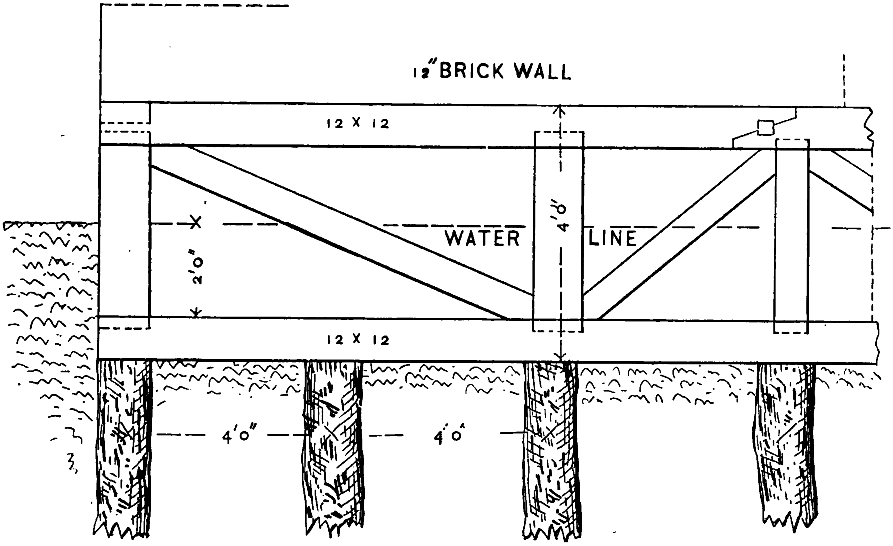


ILLUSTRATION 42.

Illustration 42 shows an elevation of framing on top of piles. This is the plan adopted in the construction of a factory built on the marshes near Hoboken, New Jersey. The building is 50 by 100 feet, and about 20 feet in height. The piles, of yellow pine, were thirty feet in length, and from nine to twelve inches diameter. After being driven, they were cut to a level of two feet below water-line, and spaced for the outside walls four feet to centers. On top of these were placed sills, twelve by twelve inches; on top of the sills were framed uprights, twelve by twelve inches, four feet long, braced from all sides; on top of uprights is placed a second sill, that receives a twelve-inch wall. The piles for wooden pillars through center are eight feet to centers. The piles for the chimney and engine-room are about twenty inches apart, with timbers crossing eath other, forming a foundation for stone slabs, on top of which is built the brickwork. The foundation of timber is cross-braced from center to outside; and notwithstanding the motion of the machinery, no unequal settlement has occurred, and perhaps has settled to one inch before becoming fixed and solid.

Thickness of Walls Given for any Number of Stories in Height.—See following table.

When it is the intention to use stone-walls instead of brick; *i. e.*, broken-range work, or quarry-faced range, add from four to eight inches to the thickness of stone-walls—*i. e.*, to the thickness given for brick-walls in these tables.

WALLS OF BRICK FOR STORES, WAREHOUSES AND BUILDINGS THAT REQUIRE EXTRA STRENGTH.

The height of walls in feet given.

100 feet high by 150 feet long	90 feet high by 150 feet long	80 feet high by 150 feet long	70 feet high by 150 feet long	60 feet high by 175 feet long	50 feet high by 160 feet long	40 feet high by 150 feet long
3 feet 0 inches thick	3 feet 0 inches thick	2 feet 6 inches thick	2 feet 4 inches thick	2 feet 4 inches thick	2 feet 0 inches thick	20 inches thick
100 feet high by 70 feet long	90 feet high by 70 feet long	80 feet high by 70 feet long	70 feet high by 60 feet long	60 feet high by 50 feet long	50 feet high by 45 feet long	....
2 feet 8 inches thick	2 feet 6 inches thick	2 feet 6 inches thick	2 feet 4 inches thick	24 inches thick	20 inches thick	....
60 feet long	55 feet long	45 feet long	35 feet long	30 feet long	....	....
2 feet 4 inches thick	2 feet 0 inches thick	20 inches thick	20 inches thick	16 inches thick	....	....

One-twelfth or one-fourteenth of the height of each story is an average for the thickness of a wall.

TABLE OF THE THICKNESS REQUIRED FOR BRICKWALLS FOR STORES, RESIDENCES, ETC.

Total height of wall in ft. to be erected.	*Total length of wall in ft. to be built.*	*B'sement story in inches.*	*First story in inches.*	*Second story in inches.*	*Third story in inches.*	*Fourth story in inches.*	*Fifth story in inches.*	*Roof in inches.*
100	100 to 125	32	24	24	20	16	16	12
100	80	28	24	20	20	16	12	..
100	45	20	20	16	16	16	12	..
90	100 to 125	32	24	20	20	16	16	..
90	70	24	20	20	20	16	16	..
90	45	20	20	20	16	16	16	..
80	100 to 125	28	24	20	16	16	12	..
80	60	20	20	16	16	16	12	..
80	45	20	20	16	16	12	12	..
70	100	24	20	16	16	16	..	12
70	55	20	16	16	12	12	..	8
70	40	20	16	16	12	12	..	8
60	100	20	20	16	16	12	..	8
60	50	20	16	12	12	8	..	..
60	30	20	16	12	12	8	..	..
50	100	20	16	16	12	..	..	..

In using the above tables for thickness of walls in Baltimore, Philadelphia, Washington, etc., the walls average more in proportion, owing to the brick being larger than in other parts of the United States. Use for eight-inch walls 8¾ inches; for twelve-inch walls, 13 inches; for sixteen-inch walls, 17½ inches; for twenty-inch walls, 21½ inches; for two-feet walls, 26 inches, etc.

Footings are twice the thickness of basement walls.

All divisions on party walls between dwellings should be at least twelve inches. When the walls are eight inches the wood beams of floors for each side, cut through them.

Springs in Cellars, etc.—After excavations are made for a building, either in city or country, there is often found a small water-course or spring. In the country it is best to tap the spring or line of water-course outside of the building, and take it away from the building, and follow a course that will prevent it returning and undermining the walls. In cases where this cannot be done in the city or country, sink and build with rough stone such size cistern that may be required for a flow of water for three or four days, and carefully build a drain from cistern, following the line of water-course to outside wall, if possible.

If there is an overflow liable to occur from freshets, tides, rain, etc., and the cellar bottom is below the line of sewer, it may be considered the best to build cemented cisterns that will fill to a certain height and have an indicator to prevent overflow or rise of water. These may be emptied by using a small force-pump.

If a cellar bottom is located in low ground, or below adjoining cellars, and a supply of water seems to permeate the soil, and accumulate, it is not safe to use any steam-pump, as it may draw water from the surroundings, and weaken the foundation walls, unless due precaution has been taken in building. Ordinary cisterns and hand-force pumps seem to act the best in such cases, by pumping water into a waste-pipe to be carried into sewer. If there is no waste-pipe, then it has to be pumped to such height that it may be emptied. Where a large spring or water-course is found on the cellar line of large structures, it is necessary to collect by drains all the water into a cemented cistern, and attach to the engine used in building a small pump of sufficient capacity to keep the water below a fixed line forty-eight hours, to prevent an overflow.

As a rule the surface of cellar bottoms should be covered with concrete, ranging from four to twelve inches in thickness, to form a smooth floor surface. Those that are wet or damp (and nearly all are more or less so) should have a layer of asphaltum over the surface, and extended up the sides to a point above where the dampness arises (see illustrations 33 and 35). The asphaltum, when used, should be protected by the laying on it a course of bricks, bedded in cement, or an additional layer of cement. If a smooth, handsome surface is desired, Portland cement should be used for the finish.

Since the article on asphaltum was written, my attention has been called to the method being extensively used by Moen's Asphaltic Cement Co., under the late patent of E. S. Vaughan, which I have looked into, and can recommend as a means of excluding water and dampness, and all disagreeable odors liable to arise in cellars. See the subjects in this book in the index.

THE ART OF PREPARING FOUNDATIONS,

WITH PARTICULAR ILLUSTRATION OF THE

"METHOD OF ISOLATED PIERS,"

AS FOLLOWED IN CHICAGO.

By FREDERICK BAUMANN, Architect.

Revised by G. T. POWELL, A. and C. E.

WITH NINETEEN WOODCUTS.

The art of constructing foundations comprises two distinct but inter-dependent parts: FIRST, *the art of treating the ground;* and SECOND, *the art of building the base.*

FIRST PART.

The Art of Treating the Ground.—All ground, from the nature of things, is *compressible*—will yield under pressure. This is owing to three different natural causes; FIRST, *general compressibility of matter*, which is so slight that in practice it causes no concern; SECOND, *imperfect packing of the constituent parts and incipient fluidity*, which induces to study and care, though positive artificial treatment be not needed; THIRD, *semi-fluidity*, which in most cases calls for positive artificial treatment. Accordingly, I shall consider the different building-grounds under the head of three distinct classes: *solid grounds, compressible grounds, semi-fluid grounds.*

Class I. — Solid Grounds. — This class comprises *rock, gravel, dry sand*, in their natural beds, and of sufficient thickness of strata. The treatment is very simple, and in most cases alike. Excavations must be made to remove loose deposits and expose the *natural bed.* Surfaces must be made *level,* because bases should not be started upon inclined planes. In this manner the most common engineering routine will ever attain good results as to foundations. The ground being, for all ordinary practical purposes, next to incompressible, differences in the weights of the various parts of the superstructure produce no manifest defects. Neither is there any considerable manifestation of piers or corners deviating from the line of the perpendicular, though, perchance, such piers or corners were not centrally supported. Concrete or no concrete, inverted arches or no inverted arches, *random work* or *work rightly considered,* the result is practically ever the same; the slight deviations from the true lines, which may occur, pass unnoticed; the builder has nought to think on the subject; his common every-day routine suffices him in all his cases, and he remains in ignorance as to the proper principles by which the true art of preparing foundations is governed. Their practice was upon ground of the first class, which prevails in most of the large cities of the country, and taught them nothing to the point; nor could they avail themselves of the experience of others, inasmuch as, beyond this present treatise, there is (as far as at present known) nothing in print even pretending to give information. The evolution of the "method of isolated piers" is but the result of modern wants as to the construction of mercantile buildings.

Class II.—Compressible Grounds.—This class comprises *clay* and *watery sand,* and mixtures of the two, a whole scale of grounds, from the border of the first class downward to semi-fluidity. The sucessful erection of any ordinarily heavy structure upon such ground involves the consistent application of two well known (and often, though loosely mentioned) principles: FIRST, *the areas of base must be in proportion to the superincumbent loads;* SECOND, *the centers of these areas of base must coincide with the axis of their loads.*

These principles are self-evident, well known, and often loosely mentioned, yet so seldom observed. It is, indeed, needless to prove that ten square feet of bearing surface, *cæteris paribus,* will bear more weight than will two square feet, or four, or nine. It is superfluous to specially make clear the fallacy of placing the axis of any load upon or near the edge of a base, or in any measure away from its very center. The natural result of such foolish proceedings would be that, as the ground yields, the base assumes an inclined position, and the axis, which must retain its original angle with the base, is thrust out of its perpendicular line, as represented by Fig. 1. It is not then these simple principles

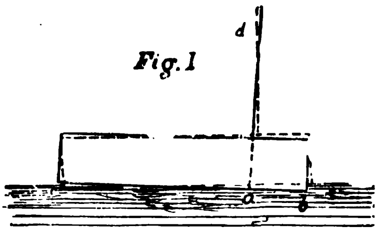


Fig. 1

that will occupy me; it is rather their varied and manifold application in the practice of this difficult "*art of building*," in which *economy*, rightly understood, is a principal factor, nay, in fact, *the* factor, which really renders it a science, which can only be attained by one who has acquired a manifold experience, and who previously has had such discipline of mind as to enable him to systematically collect, and assimilate with himself, the mental fruits of his labors.

First Rule.—*Resolve the building, upon its ground plan of the lower story, into isolated parts, and independently apportion to each its proper share of foundation.* The first part of this is of old standing, and often applied in exceptional cases—for instance, a church with a massive tower. But the mere keeping the tower separated from the other parts is of no avail, unless the latter part of the rule is observed, by special intent or by chance of circumstances, as the case may be. It is this matter of resolving a complex building into isolated parts, a task requiring experience and sagacity. Scarcely are there any two buildings alike in this respect, and the question ever arises, where shall I stop? With some buildings it may be simple, so that the old every-day routine may suffice.

Second Rule.—*Estimate the weights of all those (really and ideally) isolated parts, in order to apportion to each its due share of foundation.* To this end it is required to know the *bearing capacity* of the particular ground, and also whether or not, and in what ratio, the load may be increased in proportion to the area of base. If it were found, for instance, that the medium bearing capacity (reduced to a convenient unit) is, say two tons per square foot—meaning that under such proportionate load the ground will be compressed in a limited known ratio—and if it were further known (approximately so at least) that this ratio holds good for any amount of load, the task is at once simple. A pier weighing 120 tons must receive a base pressing an area of 60 square feet; a pier weighing 20 tons must press upon an area of only 10 square feet, and so on in this proportion. It will be found, however, that the proportion varies with the nature of the ground. Ground least fluid and most solid (dry clay) will thus give too much support to the lesser loads; ground approaching semi-fluidity will give them too little. In each case, therefore, where the properties of the ground are not fully known in advance, tests must be instituted for their ascertainment, and the apportionment made accordingly.

Third Rule.—*Determine, upon the ground section, centers (and center lines) of all (isolated) parts, which in upright section will be the axis (and axial planes) of these parts, and place the (masonry) bases so that the centers of their areas of contact will coincide with the first centers.* It means that foundations must be made to support their loads *centrally.* The observation of this rule is of the utmost importance, for upon it will depend the perpendicularity of all the walls and the corners of the structure. Let all parts have central foundations, and no inherent tendency will exist to disturb this perpendicularity. There will in such case be no particular need of any anchors, except for temporary use, while in the contrary case the strongest and best applied anchors will not suffice to preserve the *exact* normal position of the walls and corners. *Have the bottom right, and all else will come right without many further precautions.*

I comprise the above three important rules under the head of "Method of Isolated Piers," which I advance as a *scientific method* in opposition to the old *random method of continuous foundations.*

I am aware that *isolated foundation-piers* are of old date. Such isolation of piers has been, however, the *exception,* not the *rule.* Its origin is from chance and circumstance, not from logic. I, on the other hand, advance a principle which makes *isolated piers* the *rule in all cases,* and *continuous foundations the exception,* where, for instance, piers of *uniform weights* are so close to each other that the bases will interconnect.

Objection might be raised to this new method, on the ground that any building-ground may not be everywhere of the same uniform density. This circumstance will but seldom occur, and if and wheresoever it does so, the greater difficulty should be a spur to greater care and perseverance. It would in such case be requisite to make the most careful survey of the ground, to determine the degrees of variations in density, and map the same, in order to obtain a correct basis for estimation and apportionment.

The Building-ground of Chicago.—The subsoil throughout is of blue clay, covered by sand and loam, which, below the level of ground-water, become "*quicksand*" and "*blue muck.*" In the central part of the city the clay is found at a depth of about five feet from the original surface, which now is about eight feet below the established grade of streets. This clay-bed is more or less permeated by water, which enters through a network of fine gravelly veins, and through the river channel; it is, therefore, varying in its bearing capacity in proportion to its state of humidity, the driest clay of course being the hardest, and therefore the best for purposes of foundation. In the central part of the city the clay-bed has a distinct surface, covered with a scattered stratum of boulder-gravel, and is termed "*hardpan.*" It approaches the surface to within five feet. Throughout the West Division the clay is equally near to daylight, though it has no distinct surface, the loam gradually changing into clay.

From State street eastward, the dip of the clay-bed is so steep that already within one block it becomes ordinarily impracticable to reach it. Nor is this necessary, for the overlying soil answers all purposes. This soil is here an intimate mixture of clay and fine sand, in common parlance termed "*blue muck*," on account of its shifty nature; but its quality as building-ground is better than first appearances would warrant. Toward the North and South the clay is covered by a bed of fine sand, which grows in thickness with the distance from the center of the city; it becomes what is termed *quicksand* from the level of ground-water downward, which level is mostly within a few feet from the surface. *A massive stone church tower erected upon this quicksand gradually sank, within about eight months after its completion, some twenty inches, carrying with it the surrounding ground on a radius of over forty feet. There being apparently no limit to this "settling," the tower was taken down. Its weight upon the base was probably not over thirty-six pounds per square inch.*

The convenient bearing capacity of all this soil is *twenty pounds to the square inch.* With this the bases in all ordinary cases become not so widespread as to necessitate for their solid construction any cutting into the hardpan. Such proportionate load will compress the hardpan to the extent of about one inch during construction of the building, and about one-half of an inch during the next six months following, after which time the load appears to be poised upon the clay; the season, as often the popular belief is, having no share in this "settling." The compression will be greater, as a matter of course, upon the softer portions of the clay, as well as upon the loam, dry or wet; it is least upon the dry surface-sand, where this can be made available. All that is necessary is the strict application of the "method of isolated piers," so that all parts of the ground will be compressed in the same degree, causing a perfectly equable "settling." But in practice it will ever be found advisable to base calculations upon the smallest possible amount of ultimate compression, and to be guided in this matter (as we ought to be in all others) by prudent *economy;* hence I term the bearing capacity stated a *convenient* one. This matter of dividing a building into isolated parts, and estimating the weight is by no means as simple as at first it would appear, and may even in some cases offer material difficulties. Take, for instance, a building six or seven stories high, fire-proof, with fire-proof vaults in the lower stories. The outer and some of the inner walls are of full height; other inner walls are one, two or five stories less in height; some of the vaults extend through four stories, others stop in the basement; the loads become shifted by the location of the openings; there are columns bearing floors; the internal walls and columns do not become loaded as the building progresses, for floors, ceilings and plastering are not applied before the building is roofed. Now if the ultimate "settling" is kept within the limit of one and a half inches, as it ought to be, the problem of attaining a sound and perfect structure is solvable through an ordinary amount of sagacity and carefulness applied upon the "method of isolated piers;" probable differences falling within the limits of one-quarter to one-half of an inch, and causing no palpable defects.

Examples and Instances—*Being an Illustration of the "Method of Isolated Piers."*—Fig. 2 shows upright section of a pier of an outer wall, and elevation of an abutting dwarf-wall. If, as the old method would suggest, in order to furnish "all the bearing possible," the dwarf-wall is connected

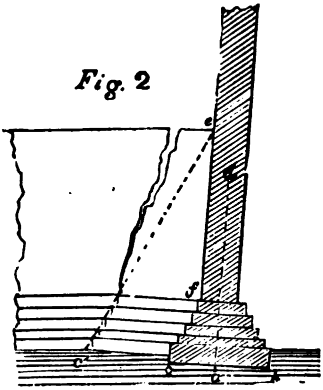


Fig. 2

with the pier at its line of intersection, *e f*, the pier will be thrust outward, and the dwarf-wall crack as indicated. The cause may readily be found. Construct the axis, *d a*, of the pier, and see whether it coincides with the center of area occupied by the base of the pier. Were the dwarf-wall *not* *connected* at *e f* and *a b=a c;*—i. e., were the construction made in accordance with the "method of isolated piers," there would be no thrust against the pier. But the usual old random mode of "all the bearing possible" extends the area of base inward to *c'*, and thereby shifts the axis of the pier *off the center* toward the outer edge of the supporting base, *b c'*, which causes the ground to be pressed into an inclined surface and, consequently, the pier to be thrust outward. Were the base of the dwarf-wall made so narrow as to cause a settling of the dwarf-wall equal to that of the pier, it would at first sight appear as though then the wall might be connected. Yet this is, nevertheless, forbidden by the circumstance that the base of the dwarf-wall would receive *all* its load before the pier would; say, one-fifth part of it. Besides, it is extremely difficult to proportion so slight a load with sufficient accuracy; and the laws of nature are very severe; but a slight deviation of the axis *d a* from the center of area of base will have its marked effect. Two rules may be abstracted from this instance.

FIRST—Let the axis of the load always strike a little way

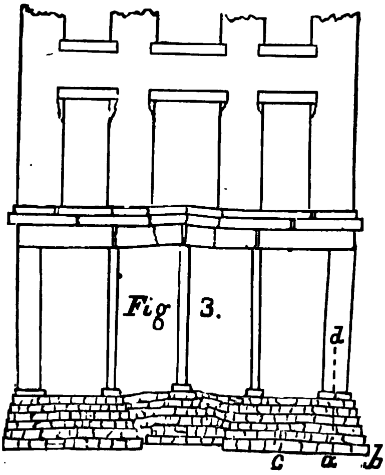


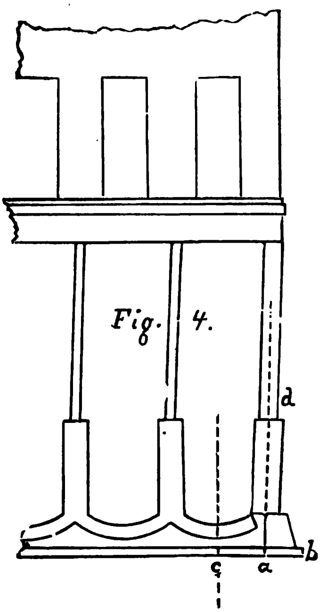
Fig 3.

inward from the center of the area of the base, in order to make sure that it will not be toward the *outside*. Any inward inclination of the pier is rendered impossible by the floor beams, while an outward inclination must be counteracted by artificial means, such as anchors, which, in all cases, are but reliable to a certain degree. Anchoring is thus reduced to safeguards; although anchors are placed on every sixth or eighth beam of each tier on stores.

SECOND—*Never connect an abutting dwarf-wall with an outer pier or wall.* Build it independently, with a distinct, clean, straight joint. In some cases it might be advisable to leave four inches of clear space, to be walled up afterward.

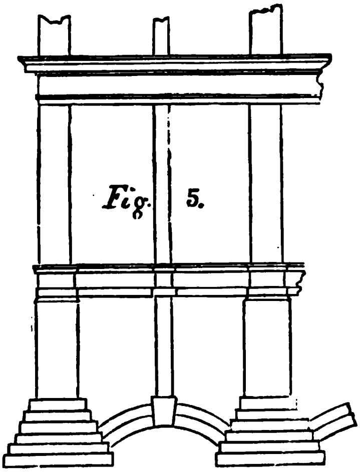
Fig. 3 shows what, in a measure, occurs to an old-fashioned four-story building erected upon continuous foundations. The middle column, having no load to sustain, retains its original position while the others are pressed downward, with results as represented.

The corner piers, if not prevented from doing so by the resistance of buildings at the right and left, are thrust outward because their axes are not centrally supported, as can be readily seen without further explanation. The foundation, in fact, resolves itself into piers, but in a manner contrary to sound engineering, giving to the lightest pier the largest

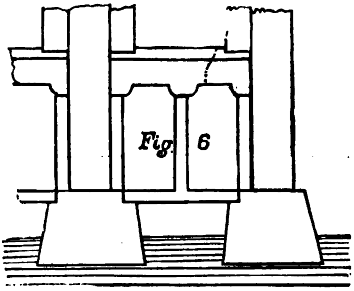


support. Before the great fire, scores of similar fronts were seen in Chicago, nor has the lesson been thoroughly understood after this great event.

Years after the "method of isolated piers" had slowly taken its course, some new comer of an architect took it upon himself to show his colleagues that he could overcome the difficulty by means of *inverted arches.* The result was a building on the corner of Washington and Dearborn Streets, as here represented by Fig. 4. The extent of the front was forty feet; the lintel was one piece of timber, connecting the piers and columns of the front, causing all to incline, parallel with the corner pier, to the extent of nearly three inches out of their perpendicular lines. It is not difficut to conceive that good inverted arches have a greater effect upon shifting the axis of load off the center of base than has a mere continuous foundation (or a continuous bed of concrete); likewise, that the thrust of the arch itself, if any such occurs, would have the tendency to *counteract* rather than enhance the difficulty arising from oblique settling of the base.

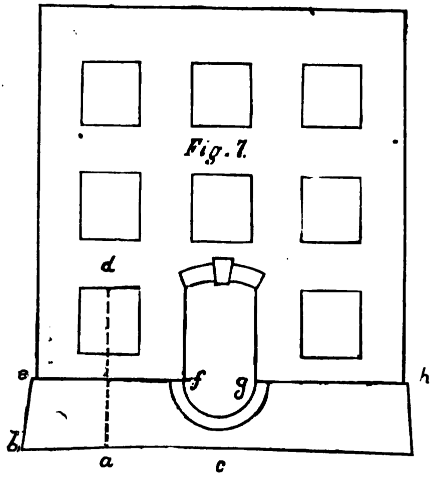


The case grows serious with Fig. 5, which represents part of a front, consisting of alternate heavy and light piers. Continuous foundations, or bed of concrete, or inverted arches, would have a tendency to thrust the corner pier outward, and to break the horizontal connections over the little piers, as has been demonstrated by the former examples. But even the smallest admissable bases might prove troublesome in regard to the little piers. In such cases, resort may be had to an entire omission of bases for such little piers, and to the introduction of some bearing connection from large to large pier for their support, as shown in Fig. 5. A case has occurred very lately in Chicago, where the bases of such heavy piers were made too small, and those of the lighter piers too large (isolated piers were here employed without method). The effect was that the sinking heavy piers hung themselves, with part of their weight, by means of very stiff horizontal connections, on the little piers, and literally crushed them. Had these crushed piers been stronger than the horizontal connections, the latter would become seriously damaged. As it was, the building underwent jack-screw operation and insertion of new piers. In cases where there are mere mullions in the larger lower windows, as represented in Fig. 6, if the mullions are supported on iron construction from large piers on each side, piers under will not be required; otherwise, direct foundations under these mullions will be necessary, and the piers to be proportioned to sustain the load above.



A prominent building lately erected with such mullion piers upon direct foundations was merely saved by the fact that, *firstly*, it was placed upon old, well settled foundations, and, *secondly*, that the three upper stories of the design were omitted, leaving the building, as it now stands, four stories high. The consequence, thus far, is the mere fracture of one of the powerful stone lintels covering the basement openings (as indicated by dotted line).

The case assumes a different aspect under Fig. 7, yet it is readily shown to belong to the same class. In 1852, I constructed the front of a blacksmith's shop in manner shown by Fig. 7, with this result, that the keystone of the doorway arch dropped downward. The inverted arch owed its existence to the universal random idea of "get all the bearing you can." But when the piers *e f* and *g h* are considered by themselves, it is not difficult to observe that, through the very introduction of this inverted arch (or continuous rubble wall or concrete), the axes of these piers become shifted off the centers of their bases, and, consequently, thrust outward; hence the dropping of the keystone. The fact is, that a front thus constructed compresses the ground under its base to a *convex* plane, while on the other hand, by the principle demonstrated in the discussion of Fig. 2, it should be so constructed as to compress the ground to a plane slightly *concave*, which may be readily effected by omitting the foundation under the opening.



The reader will now fully understand the reason why the arches over almost all large openings (in churches, etc.) have more or less parted. He will understand from Fig. 8 why the arches over the center of the ill-fated Court-House wings were rent. The law acts with unerring certainty, no matter what the extent of the front, no matter how slight the cause.

But to furnish a most striking example of the minuteness with which this law operates, I produce Fig. 9, which is intended to represent a view of the east gable of the (destroyed) celebrated Crosby Opera House. The foundation wall, twelve feet high, was built of rubble stone in

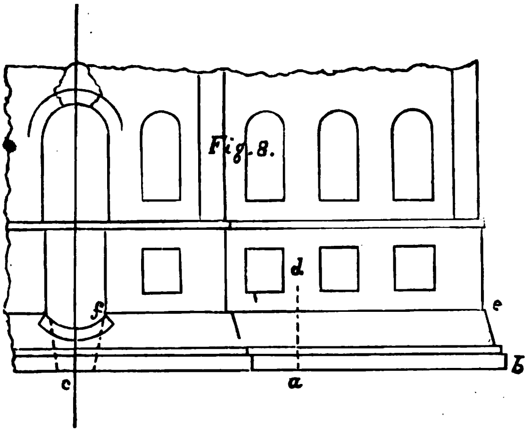


Fig. 8.

cement mortar, and had ample time to set, since the brick wall was not started thereon until about two months afterward. The base was five feet wide upon the hardpan, the brick wall twenty inches thick for twenty feet high,

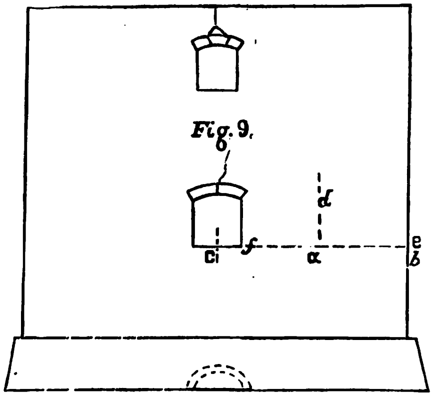
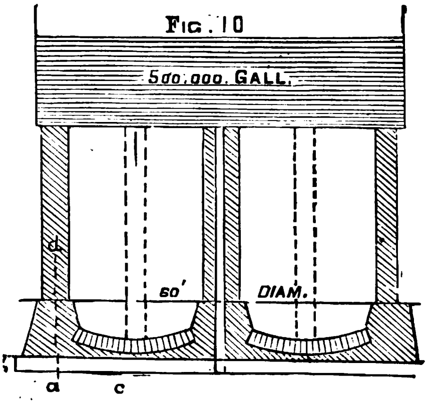


Fig. 9.

and sixteen inches for the following sixty feet. The load upon the base was consequently about twenty-six pounds to the square inch. The whole weight of wall and base was 850 tons, less twenty tons omitted by the two openings.

The ultimate settling of the wall could not have been over two and a half inches, yet the slight reduction of the load by only twenty tons, at its center, from the total load of 850 tons, caused the base to assume a slightly convex plane, so that both corners were somewhat thrust over, as indicated by the parting of the arches over the openings, which parting was so decided that the cracks were plainly seen at 160 feet distance, from the opposite side of State Street,* and caused a whisper among the unsophisticated passers by to the effect that the house was unsafe. And all this from so little a cause! The most remarkable feature of this case, however, is that the base, *thirty-two feet thick*, as it were, from the hardpan to the sill of the lower opening, did accommodate itself readily to the assumed curvature of the ground; that, in fact, all this mass of solid brick and stone work acted as though it were possessed, in a measure, by a minute degree of quassi-fluidity. This ought to show to satisfaction, if not a proper consideration of the case by itself did, that compressible ground cannot be spread over at random by concrete, or any kind of masonry, and thereby made exempt from the operations of the "law of convex deflection." All such masonry, of whatsoever kind, will, from its nature,

FIG. 10



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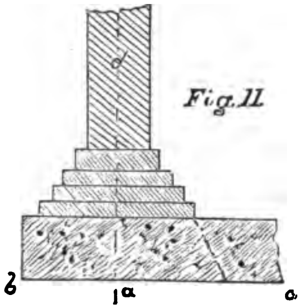
* This gable was a mere court wall, receding ninety-three feet from the line of State Street, upon which, immediately afterward, a fine building was erected by the owner of the Opera House.

yield and accommodate itself to such curvatures of the ground as the different loads at different places will naturally produce.†

To give one of the most flagrant instances of what happens from non-observation of the biddings of the "law of convex deflection," I introduce (Fig. 10) a section of the old water-reservoir structure on Adams Street, erected 1854. The consequence was the the immediate discomfiture of the structure on the first day when the water was let on. Even if other causes had not enhanced this result, the "law of convex deflection" alone would have been sufficient for its production. To render the concern serviceable, all openings were walled up and an intermediate inner wall was built, as indicated by dotted lines. Nothing could have happened had the foundation been prepared in accordance with the "method of isolated piers."

1. *Cross section through an outer wall.—Fig.* 11. It will readily be perceived that, by dint of this continuous bed of concrete, the axis *d a* is shifted off the center of its base; the clay beneath will consequently be compressed to a *convex plane*, with a tendency to thrust the wall out of its perpendicular line. This tendency need, however, not become realty, because of the very probable rupture of the bed of concrete, as indicated in Fig. 11, or else because the cross anchoring will be so effective as to prevent such occurrence to an



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† Omitting some of the base at the center, by means of an arch as indicated, would have preserved the exact perpendicular state of the corners, so as to leave the arches intact.

extent that will be noticed by a non-expert. Had this wall an independent central base, as dictated by the "method of isolated piers," no possible contingency could ever arise.

2. Considering the large inequality of the weights of the piers of the outside walls, the heavier piers will sink down, in some measure, proportionate to the weight of pier and size of base upon the clay, such as it may assume for itself, while the little piers will almost wholly retain their original levels. The difference may possibly not be very considerable, and escape the eye of the non-expert, but occur it must, by dint of inexorable law.

3. Taking a view of a corner with adjoining pier, Fig. 12

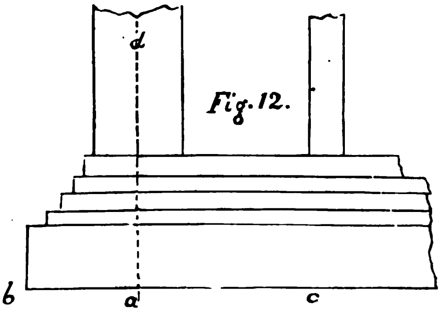
Fig. 12.

the case represents itself similar to what it does in Fig. 11, with this difference, however, that in Fig. 11 the concrete is bare and may be readily ruptured, while here the concrete is strengthened by a mass of the most excellent masonry, and may not break so as to save the corner from being thrust outward. Besides, the anchors, as usually applied, get no

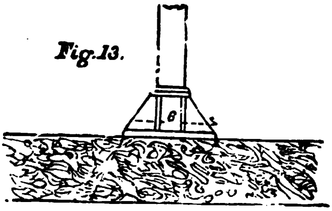
Fig. 13.

hold at the corners. To hold them would require a longitudinal and cross anchoring within the thickness of the walls, from corner to corner, a troublesome and expensive proceeding. Under the "method of isolated piers," with observance of the biddings of the "law of convex deflection," the corners would take care of themselves without anchors.

4. Taking a section through one of the intended internal piers, Fig. 13, the case assumes a very serious aspect. The load per column is said to be upward of 380 tons; the column is to stand upon an iron stool, with bottom plate six feet square, bedded on the bare concrete. To arrive at any accurate, or even approximate, estimate of the efficacy of this bed of concrete, under existing circumstances, is simply a matter of impossibility. A mechanical estimate to this effect requires a knowledge of its exact absolute and crushing strength, as well as of the exact degree of the elasticity and incipient fluidity (yielding property) of this concrete. Even if these properties were ascertained from samples, it would by no means follow that the bed, just at such particular place, is altogether precisely according to the samples. Trials have been made by loading plates one foot square with as much as thirty and more tons upon each. To conclude from this trial upon the nature of the case is, I believe, a fallacy. Even if one square foot would bear, without damage to the integrity of this bed of concrete, say 100 tons during a week, the conclusion is by no means warranted that it will carry *for all time to come* 380 tons upon a spot six feet square, with absolute and infallible certainty. (Actual practical judgment, with an allowance of one-quarter of the load that produces any movement of depression on the earth, will be safe.) The load, as the case is, must be trusted on *chance*, instead of on mathematical certainty, and is, therefore, in a technical meaning *insufficiently supported*, which involves by no means a predic-

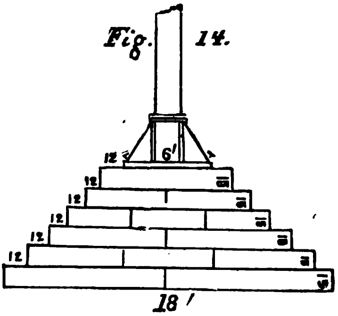

Fig. 14.

tion that in reality the support *will,* or *must,* fail. It simply means that it *may* fail. Any construction in building that is not secure by dint of mathematical certainty, is technically insecure, and therefore condemnable. How differently does this case present itself under the light of the "method of isolated piers," as is illustrated by Fig. 14. Here the hardpan is loaded to a ratio of about twenty pounds to the square inch. With a pier well bedded, and securely constructed out of the most beautiful material so readily at hand in Chicago, it is mathematically certain that the ultimate "settling" will be (about) one and a half inches. Besides, this construction would have the point of economy in its favor.

Concrete.—Good concrete is always made up with cement-mortar. This artificial conglomerate rock is spread upon the building-ground at large, or upon the bottom of foundation trenches, in a thickness varying, as the case may be, from one to five feet for the purpose of an "*equalizer.*" Concrete work at best is *random work,* that may and may not do good service. Upon hard and practically incompressible ground it is superfluous, as a matter of course, except what may be required for the bedding of footing courses. Upon compressible ground it will, *under some circumstances,* accommodate itself to the deflections of the ground caused by superincumbent loads, and thus may, if circumstances concur, be of *very serious damage* to the structure, under the "law of convex deflection," as before demonstrated. I reject *random work* as being contrary to the spirit of the present age, and recommend in its place the "*method of isolated piers*" for foundations.

Concrete is applicable in foundations as a *base* in place of other masonry. Its application is there justified in all cases, where it chances to be the *cheapest* material. It is in this sense one of the means at the hands of the engineer for the attainment of his ends.

Class III.—Semi-Fluid Grounds.—This class comprises *silt, marsh, peat,* and the like. When gravel or rock can be found within practicable distance, piers of some kind may be sunk upon it; but ordinarily resort is had to artificially condensing the ground by means of *piling.*

SECOND PART.

The Base is alike a means of *support* as it is a means of *spreading out*, in order to convey the pressure exacted by the load upon such area of the ground as has been determined under the "method of isolated piers." The base therefore must be in every respect *solid;* the pressure to which it is subjected must in no way move its constituent parts. The Chicago material for bases is: *Dimension stone*, hard lime rock, of most any dimensions, from eight to twenty inches thick, and with even beds. There can be no better material in the whole world than this dimension stone. There is also *rubble stone* of the same rock, hard, flat bedded, handy as to size. Concrete, being inferior to rubble work, and besides being more costly, is out of the question, at least under a reasonable view of employing means to an end. For dimension stone I have adopted the rule of making the offsets somewhat less than the thickness of stone, though I know of no instance of an evil result from offsets being even more than equal to the thickness of stone. For rubble I have adopted four inches of an offset to each foot of height. For concrete I should reduce the offset to three inches. Figs. 15, 16, 17 represent bases accordingly, all under the supposition that the weight of the wall requires a width of base of six feet eight inches.

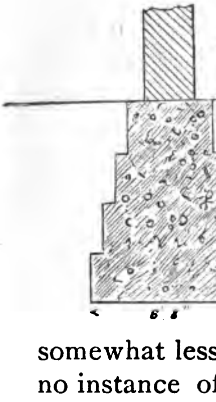
Fig. 15.

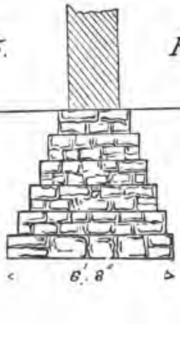
Fig. 16.

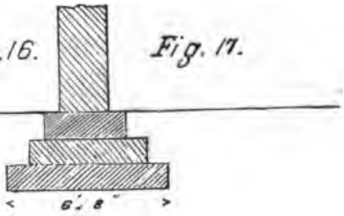
Fig. 17.

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making evident the absurdity of employing concrete in Chicago foundations.

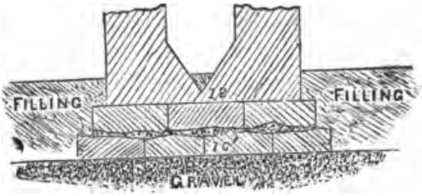
The money point grows more in favor of rubble stone as the base is narrower, and more in favor of dimension stone as it is wider, as can be readily estimated.

Pier bases ought in all cases to be wholly constructed of dimension stone.

The *bedding* of the base on the ground offers but little difficulty. Upon sand and loam, dry or wet, it beds itself without trouble. Clay is best covered first with a thin layer of gravel or broken stone, rammed into the surface, and grouted with liquid cement-mortar. A layer of concrete, from two and a half to four inches thick, and rammed partly into the surface, answers the same purpose. Upon the surface thus prepared mortar is spread, and the stone bedded.

The *mortar* ought always to be good cement-mortar, with sand of very coarse, gravelly nature as its component. For joints of two or more inches in thickness, between dimension stones which happen to have uneven beds, a mortar, made of two parts of roofing gravel and one of fresh cement, has answered excellent purpose. By this the expense of dressing the stone is saved, and yet the end attained with all the certainty required in ordinary cases.

Fig. 18.

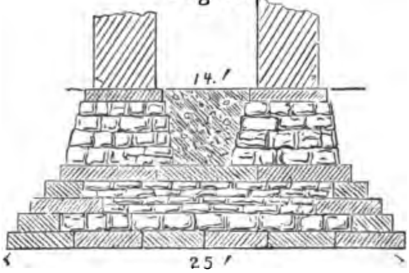


I conclude the subject with Figs. 18 and 19, representing bases of two of the tallest chimneys in Chicago.

Fig. 18 is the base of the chimney erected in 1859 for the Chicago Refining Company, 151 feet high, 12 feet square at foot. The base, merely two courses of heavy dimension stone, as shown, is bedded upon the surface gravel near the mouth of the river, there recently deposited by the lake. The mortar employed in the joint between the stone is roofing gravel and cement. The area of base is 256 square feet, the weight of chimney, inclusive of base, 625 tons, giving a pressure of thirty-four pounds to the square inch. This foundation proved to be very perfect.

Fig. 19 is the base of the chimney erected in 1872 for the McCormick Reaper Works, which is 160 feet high, 14 feet square at the foot, with round flue of 6′ 8″ diameter. The base covers 625 square feet; the weight of the chimney and base is approximately 1,100 tons; the pressure upon the ground (dry, hard clay) is, therefore, 24⅓ pounds to the square inch. This foundation too proved to be most perfect in every respect. 24⅓ pounds per square inch is a moderate load for piers.

Fig. 19.



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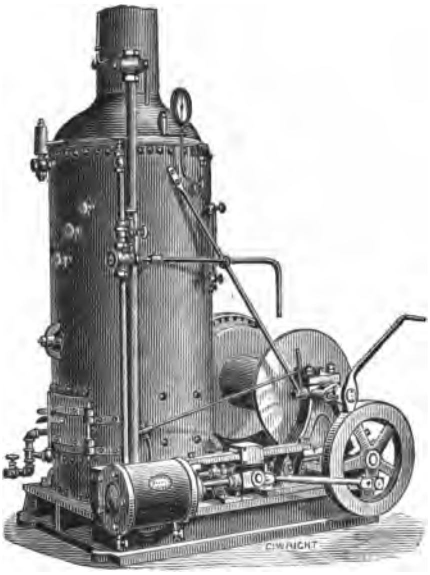

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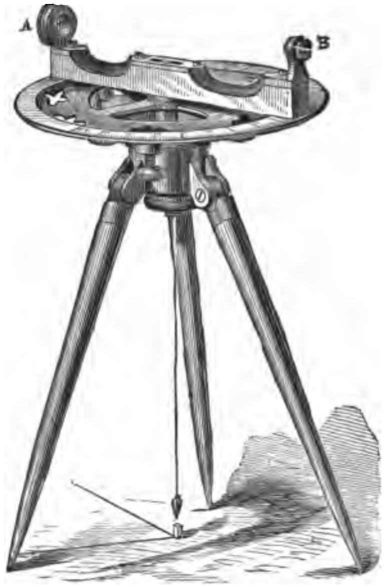

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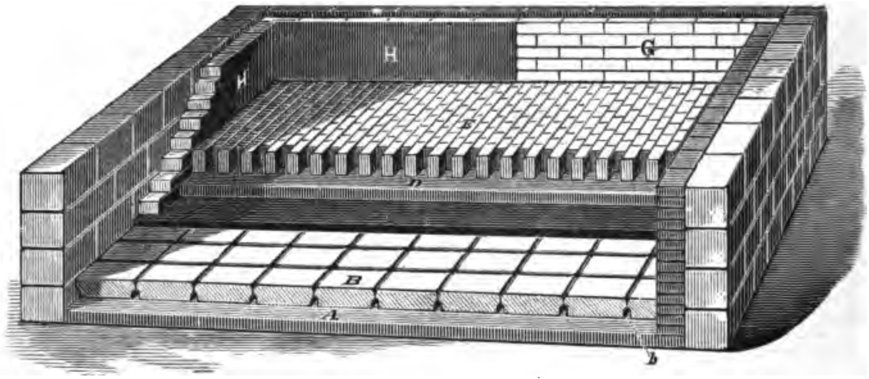

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